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MATHEMATICAL MODELING OF SINGLE DROPLET TRAJECTORIES IN COMBUSTOR FLOW FIELDS

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ABSTRACT

In liquid hazardous waste incineration, the ballistics of some large single droplets can limit destruction efficiency. Mathematical modeling and experimental work were performed in this study to examine the behavior of individual fuel droplets sprayed into a combustor, to determine which parameters could influence incinerator effectiveness. A computer model has been developed to predict the motion, heating and evaporation of such a droplet in a heated environment. The model is based on droplet behavior governed by fluid mechanics and contains formulations to predict the effect of droplet spacing on drag and evaporation as well as the effect of evaporation on drag. The gas flow field can be specified with mean velocities or a randomly fluctuating turbulent field, based on experimental values for the standard deviation of the velocity. Numerical predictions of the initial heating and evaporation of an isolated burning droplet are compared to experimental results. The predictions, which utilized measured temperature and velocity gas fields, compared well to experimental observations. The correlation of droplet penetration with droplet incineration suggests that incinerator failure modes may be predicted on the basis of droplet atomization parameters and gas field conditions. A User's Manual for the code is included as an appendix to the report.

TABLE OF CONTENTS

ABSTRACT....iii

LIST OF FIGURES....vi

LIST OF TABLES....vi

1.0 EXECUTIVE SUMMARY....1

2.0 INTRODUCTION....7

3.0 THEORY AND FORMULATION - DROPLET SPECIFICATION....11

- 3.1 The Uncoupled Problem....11
- 3.2 Droplet Drag....11
- 3.3 Droplet Heating....15
- 3.4 Droplet Evaporation....17

4.0 THEORY AND FORMULATION - FLOW FIELD SPECIFICATION....19

- 4.1 Geometry....19
- 4.2 Velocity Profiles....19
- 4.3 Turbulence....22
- 4.4 Temperature Profiles....25
- 4.5 Gas Properties....26

5.0 NUMERICAL PROCEDURE....27

6.0 CODE ORGANIZATION....30

7.0 USER FRIENDLY INPUT GENERATION CODE....35

8.0 MODEL CAPABILITY....36

9.0 POSSIBLE CODE ENHANCEMENTS....37

- 9.1 Group Combustion....37
- 9.2 Droplet Composition....37
- 9.3 Droplet Evaporation....38

10.0 COMPARISON OF EXPERIMENTAL RESULTS WITH NUMERICAL PREDICTIONS....39

11.0 CONCLUSIONS....41

12.0 REFERENCES....42

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Table of Contents (continued)

APPENDIX A USER'S MANUAL - LISTING AND DESCRIPTION OF INPUT VARIABLES....A-1

APPENDIX B PROGRAM LISTING, 2-DIMENSIONAL VERSION....B-1

APPENDIX C PROGRAM LISTING, 3-DIMENSIONAL VERSION....C-1

APPENDIX D LISTING OF SAMPLE OUTPUT FILES....D-1

APPENDIX E PROGRAM LISTING, INTERACTIVE INPUT GENERATION CODE....E-1

LIST OF FIGURES

No.		PAGE
1	Droplet trajectories—experimental results and model predictions	4
2	Schematic of bench scale combustion facility	9
3	Combustor geometry for liquid injection model	20
4	Gas velocity descriptions	21
5	File and subroutine structure for two and three dimensional codes	31
A-1	Screen 1. Incinerator specification	A-12
A-2	Screen 2. Droplet properties	A-13
A-3	Screen 3. Output flags and default values	A-14
A-4	Screen 4. Initial droplet properties	A-15

LIST OF TABLES

No.		PAGE
1	COMPARISON OF EXPERIMENTAL RESULTS WITH MODEL CALCULATIONS	3
A-1	MODEL INPUT VARIABLE DEFINITIONS	A-7

1.0 EXECUTIVE SUMMARY

A multi-task contract has been awarded to Energy and Environmental Research Corporation (EER) by the U.S. Environmental Protection Agency (EPA) to examine various aspects of the combustion process. The first task in the Fundamental Combustion Research program (FCR III) is to examine more closely the characteristics of a single droplet in a combustion environment. This report is a summary of the modeling work performed by EER to predict the trajectory and the evaporation of a single droplet. It includes a description of the theory, development and operation of the computer code and is accompanied by a User's Manual. This computer code is to be used in conjunction with experiments which are performed by EPA's Combustion Research Branch (CRB) in their in-house research program. This model is applicable to liquid injection hazardous waste incineration.

The model developed for this program is expected to increase the understanding of droplet combustion in liquid injection incineration. It is quite important to know the behavior of individual droplets in a hazardous waste incinerator. In these incinerators, destruction of waste must be accomplished to a degree of greater than 99.99 percent. The incinerator is said to fail if this destruction efficiency is not achieved. If there are droplets which are larger than the mean droplet size, they tend to concentrate on the outer edge of the spray core, with sometimes unpredictable behavior. This model can be used to help predict the behavior of these rogue droplets, and to determine what additional information might be required to fully characterize the incinerator.

The computer model for predicting a droplet's trajectory was adapted from a model developed by Ayers et al. at University of Sheffield for the U.S. Air Force Office of Scientific Research.[1] The work presented by University of Sheffield included an algorithm for predicting droplet trajectories in three dimensions, including droplet evaporation and initial heat-up effects. The model was used to predict the environment inside a gas turbine combustor, primarily as a tool to assist in combustor design. Starting with the equations provided by Ayers et al., the computer model was written in FORTRAN

IV. Two models were developed—one to characterize a droplet's path in two-dimensional space and the other in three-dimensional space. Initially the two-dimensional version was written for an IBM PC, but the three-dimensional version, requiring much more storage space, was maintained and executed on an IBM 3070 mainframe computer. Subsequently, the three-dimensional version has been modified to be manageable by an IBM PC/AT.

The initial effort for the FCR III program was to examine the effects of droplet spacing on droplet drag. Experiments were performed at CRB to determine this effect, and empirical relations were developed from the experimental results. The next effort examined the effect of evaporation on drag. It was postulated that as a droplet evaporates, the environment immediately surrounding the droplet will change, changing the drag force on the droplet. The theory of Eisenklam et.al.[2] was incorporated into the model to account for the effect of evaporation on drag. The effect of burning has also been included into the evaporation equation, based on Labowsky's theory that the burning rate of many droplets can be expressed as a function of the burning rate of an isolated droplet.[3] The original model only accounted for evaporation and not burning. Finally, the effect of turbulence in the background gas was included in order to provide a more realistic model of the conditions within an actual incinerator.

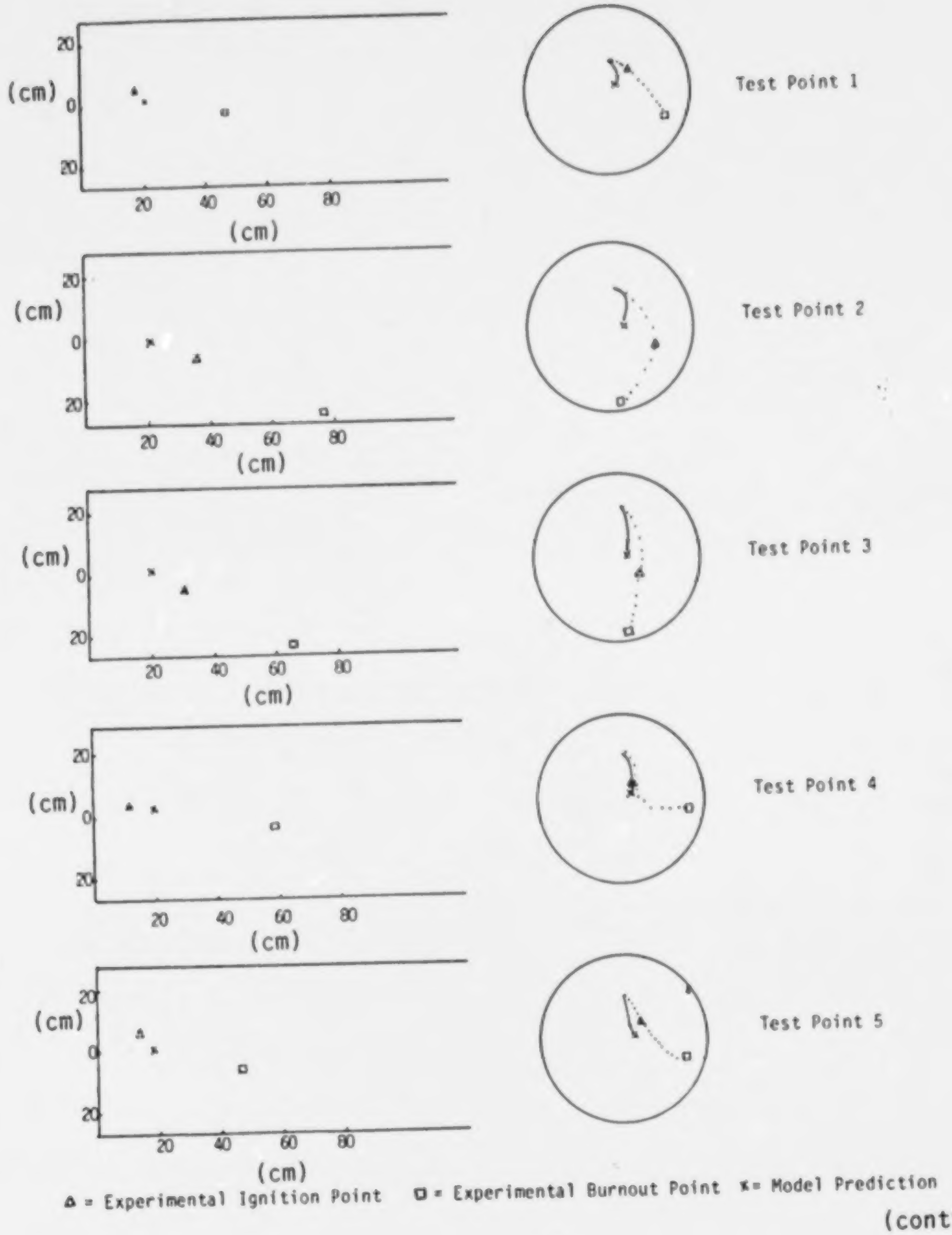
Experiments were performed over a wide range of droplet and flow field conditions. Corresponding numerical predictions are compared to experimental results in Table 1 and Figure 1. Experimental results were recorded for location of droplet ignition and final burnout, whereas the model predicts only burnout location. Model predictions show penetration into the combustor to approximately the same location as the experimental ignition point for most test cases. However, the time predicted for droplet heating to the ignition temperature is about one-third to one-half of the time predicted for droplet burning, which is approximately the order of magnitude seen in experimental testing. It is not currently understood why the model predicts burnout too early. This could indicate oversimplifications in the model or perhaps some physical phenomena which are unaccounted for. Another possible reason for the inconsistency is the fact that a multi-component fuel was used

TABLE 1. COMPARISON OF EXPERIMENTAL RESULTS WITH MODEL CALCULATIONS

		DROPLET INJECTION PARAMETERS				EXPERIMENTAL RESULTS IGNITION/BURNOUT POINT			MODEL RESULTS BURNOUT POINT		
Test Point No.	Test Variable	Vel (m/s)	Dia. (μm)	Spacing (μm)	Angle (deg)	Axial (cm)	Radial (cm)	Angle (deg)	Axial (cm)	Radial (cm)	Angle (deg)
1	Nominal	7.0	210	510 x 64	30	15/45	7/15	335/245	17.6	2.9	304
2	Spacing	7.0	210	510 x 1	30	35/75/	8/25	240/200	20.7	2.7	276
3				x 2		30/65	5/23	240/200	19.0	2.7	292
4				x 3		10/55	6/20	330/250	18.4	2.8	299
5				x 8		10/45	6/18	330/240	18.0	2.9	302
6				x 16		25/40	8/11	270/260	17.8	2.9	303
7	Velocity	4.9	180	340 x 64	30	15/25	5/10	330/270	10.3	6.0	343
8		9.1	210	640 x 64		30/60/	8/15	300/225	21.4	2.0	250
9	Size	8.5	250	620 x 64	30	35/60	8/13	270/225	28.9	6.1	203
10		8.5	315	615 x 64		45/70	10/20	270/225	44.4	19.5	193
11	Angle	7.0	210	510 x 1	0	20/75	16/16	330/330	25.5	14.2	350
12				510 x 64	0	20/45	16/16	330/330	20.2	14.5	353
13				510 x 64	45	25/50	8/12	270/270	14.1	2.9	212

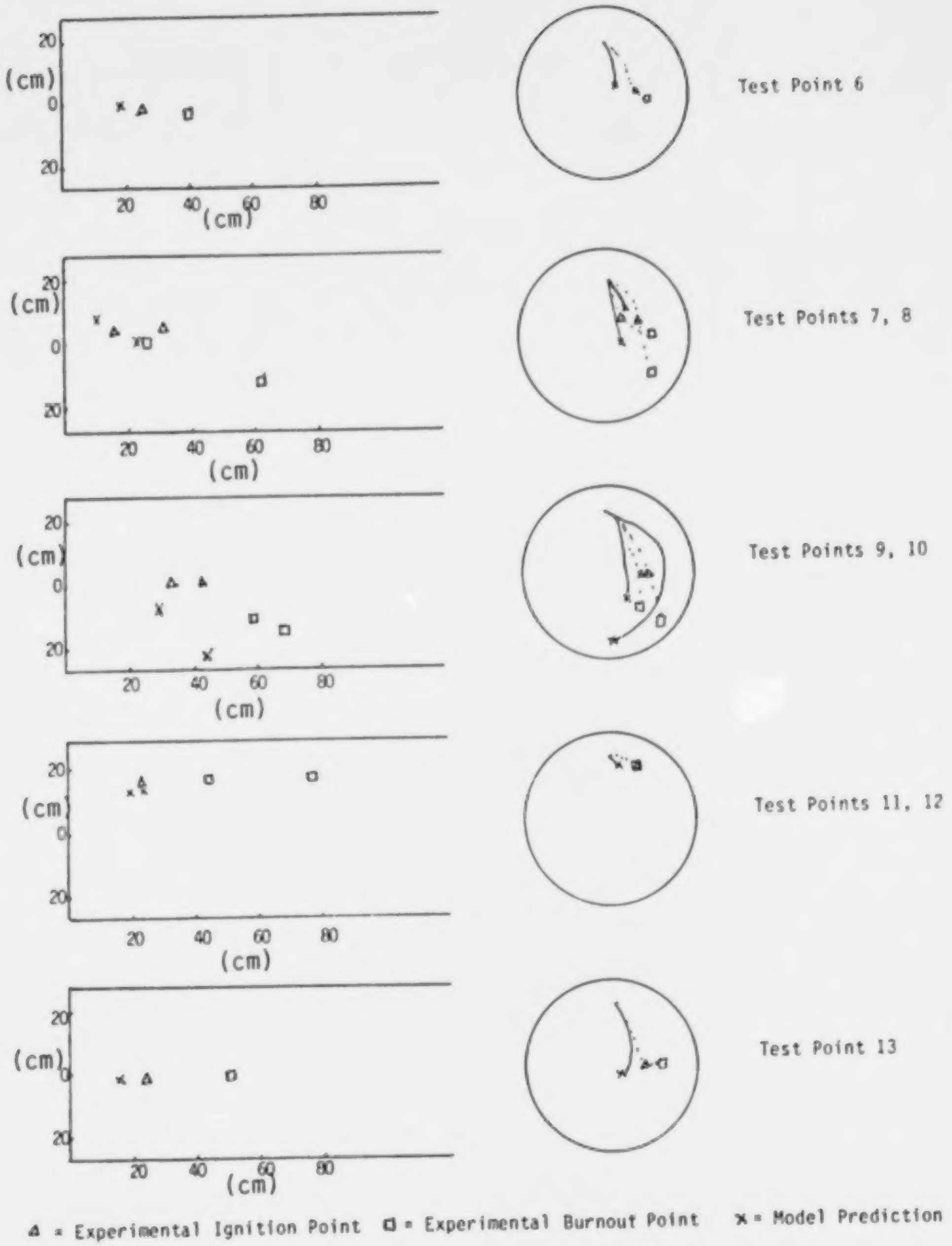
NOTE: Experimental and model results are given in cylindrical coordinates.

Figure 1. Droplet Trajectories--Experimental Results and Model Predictions



(continued)

Figure 1, concluded



in the experiments which was difficult to characterize and model correctly. The model assumes that the fuel has a single boiling point, with no evaporation until it heats up to the boiling temperature. In addition, it assumes a homogenous droplet with constant droplet properties. These assumptions are not totally valid for a multi-component fuel with a variable boiling point (depending on the percentage of various constituents) and hence the predicted droplet penetration may be skewed.

The model allows the user to predict droplet trajectories within an incinerator at a variety of initial droplet and background gas conditions. Nevertheless, there are some limitations to the code. The geometry of the incinerator is limited, in the 3-D case, to a circular cylinder. Dimensions are specified as program inputs. Eventually this code may be expanded to handle droplet sprays and group combustion, but presently it is assumed that only one droplet is injected at a time. Another limitation is the characterization of the fuel. It is assumed that the droplet properties are constant with temperature, and that there is a single boiling point for the fuel. This is not realistic for all fuels, but is an assumption necessary to simplify calculations.

2.0 INTRODUCTION

As part of the Fundamental Combustion Research Program (FCR III), the Environmental Protection Agency (EPA) has contracted with Energy and Environmental Research Corporation (EER) to provide numerical modeling support to a variety of the Combustion Research Branch's (CRB) in-house research efforts. Task 1 in the FCR III contract (68-02-4247) calls for EER to provide a computer program describing the trajectory and burn-out of single droplets injected into a complex combustion flow field. This computer code is to be exercised in conjunction with CRB experiments evaluating incineration of liquid hazardous waste droplets. This report describes the theory, development and operation of the computer code.

The combustion of liquid fuels in most practical combustors is, in general, dominated by the overall dynamics of the fuel spray and by the combustion of particle clouds, rather than by the trajectories of single droplets.[4] However, single droplet behavior can be important in predicting the behavior of large rogue droplets which exist outside the main flame zone. In considering the incineration of liquid hazardous waste, primary concern is focused on achieving waste destruction efficiency in excess of 99.99 percent. For analysis purposes it is convenient to consider the problem from a "failure mode" perspective, that is, to evaluate processes leading to waste destruction inefficiency. One such failure mode of potential importance is for a single large droplet to penetrate or bypass the main flame zone. For example, the escape of one rogue 300 μm droplet out of two million droplets with mean diameter of 50 μm will lead to a destruction efficiency of less than 99.99 percent. Measurements of droplet size distribution in various fuel sprays have found diameters of 100 to 500 μm, an order of magnitude larger than the mean.[5] These rogue droplets tend to concentrate at the outer edge of the spray core. The subsequent fate of these individual droplets is then of paramount importance to achieving required waste destruction efficiency.

CRB has established an experimental research program where an array of mono-sized droplets are injected into a swirling combustion environment. By systematically varying the droplet injection parameters and the background gas combustion aerodynamics, information will be gained to define the potential importance of rogue droplets in creating a failure mode. The experimental configuration involves a horizontal, axisymmetric furnace with a swirl stabilized burner located on the centerline. A schematic of this facility is shown in Figure 2. Mono-sized droplets with controllable droplet-to-droplet spacing are injected through a slot on the front face of the furnace. The mechanical configuration allows both the initial diameter and angle of droplet injection to be controlled.

EER had previously developed 2-D and 3-D versions of a droplet trajectory code which were direct adaptations of a model developed at the University of Sheffield for the U.S. Air Force Office of Scientific Research.[1] The initial FCR III effort was to modify the original codes for operation on the IBM PC/AT for use at CRB. After delivering the initial version of the droplet code to EPA and assisting EPA personnel in operation of the code, effort shifted to enhancement of the calculational procedures. Specifically, effort has been concentrated on adding programming logic to account for:

- the impact of droplet-to-droplet spacing on droplet drag,
- the impact of evaporation rate on droplet drag, and
- the impact of flow field turbulence on droplet trajectory.

Code modifications were based on experimental results obtained in the CRB in-house experiments as well as available literature.

To enhance the utility of the droplet codes, input files for both the 2-D and 3-D versions may be created and modified through an interactive program written for use on the IBM PC/AT. Input files for both versions may be directly accessed and executed on the personal computer.

The following section of this report contains a description of the theory and formulation of the problem and the specification of the heated environment into which the droplet is injected. Following this, the numerical procedure is outlined and the organization of the code is explained. The limitations of the code are described, along with the possibilities for code enhancement.

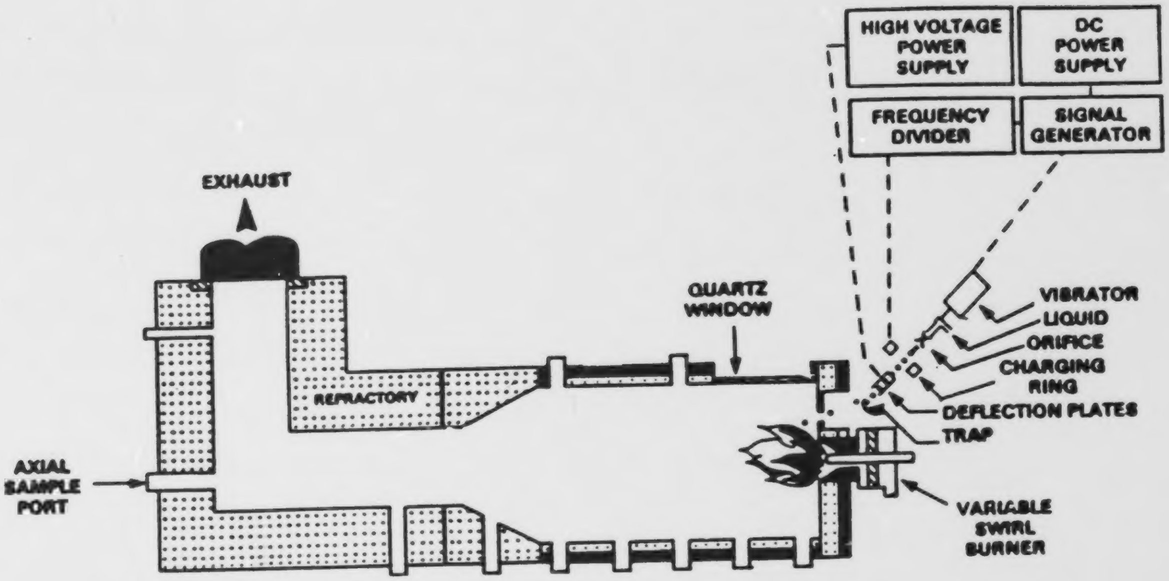

HIGH VOLTAGE POWER SUPPLY
DC POWER SUPPLY
FREQUENCY DIVIDER
SIGNAL GENERATOR
EXHAUST
QUARTZ WINDOW
VIBRATOR
LIQUID
ORIFICE
CHARGING RING
REFRACTORY
DEFLECTION PLATES
TRAP
AXIAL SAMPLE PORT
VARIABLE SWIRL BURNER

Figure 2. Schematic of Bench-Scale Combustion Facility

Finally, the predictions from the model are compared to the experimental results from the in-house work at EPA. The appendices provide examples of the codes and sample outputs, as well as a User's Manual containing a detailed description of the input variables.

3.0 THEORY AND FORMULATION - DROPLET SPECIFICATION

An accurate model of a droplet trajectory requires an accurate description of the time-varying parameters of the droplet, namely the droplet's velocity, temperature and size. Each of these droplet characteristics will be examined more closely in this section, developing a model of an actual droplet of hazardous waste within an incinerator.

3.1 The Uncoupled Problem

A droplet which is injected into a heated incinerator will evaporate and burn. The heat released from the burning droplet causes the flow field to heat up which in turn affects the droplet's burning rate (i.e., the two processes are interrelated). However, in order to greatly simplify the model, the problem has been uncoupled, and the droplet burning is assumed to have no effect on the flow field. If the problem were coupled, it would be elliptic, but with the above assumption, the problem is an initial value one. The equations of motion are solved using an explicit finite differencing technique, and the equations of heating and evaporation are solved using analytical solutions which are valid for sufficiently short timesteps.

3.2 Droplet Drag

The equations of motion on a single droplet are written considering drag and gravity to be the only external forces,

$$\frac{\partial x}{\partial t} = u \qquad 3.2.1$$

$$\frac{\partial y}{\partial t} = v \qquad 3.2.2$$

$$\frac{\partial z}{\partial t} = \frac{w}{y} \times \frac{180}{\pi} \qquad 3.2.3$$

$$\frac{\partial u}{\partial t} = \frac{3\ \rho_g\ C_D}{4\ \rho_\ell\ D} (u - u_\infty)^2 - g_x \qquad 3.2.4$$

$$\frac{\partial v}{\partial t} = \frac{w_2}{y} - \frac{3\ \rho_g\ C_D}{4\ \rho_\ell\ D} (v - v_\infty)^2 - g_y \qquad 3.2.5$$

$$\frac{\partial w}{\partial t} = \frac{-wv}{y} - \frac{3\ \rho_g\ C_D}{4\ \rho_\ell\ D} (w - w_\infty)^2 - g_z \qquad 3.2.6$$

where u, v, and w are the droplet's axial, radial, and tangential velocities, x and y are its axial and radial positions, and z is its angular position in degrees. D is the droplet diameter and C_D is the drag coefficient. The velocities of the environment through which the droplet travels are noted as u_∞, v_∞, and w_∞, and the gravity forces in the x, y, and z directions are noted as g_x, g_y, and g_z. ρ_ℓ and ρ_g represent the density of the liquid droplet and the gas, respectively.

The Reynolds number, Re, is defined by the droplet's relative velocity through the gas:

$$Re = \frac{D\ \rho_g}{\mu_g} \left[(u - u_\infty)^2 + (v - v_\infty)^2 + (w - w_\infty)^2\right] \qquad 3.2.7$$

where μ_g is the viscosity of the background gas. The drag coefficient of an isolated droplet has been calculated based on this Reynolds number from an empirical relation of Dickerson and Schuman[6] recommended by Ayers et al.,[1]

$$C_D = \begin{cases} 27\ Re^{-0.84} & 0 < Re < 80 \\ .271\ Re^{0.2217} & 80 < Re < 10^4 \\ 2 & 10^4 < Re. \end{cases} \qquad 3.2.8$$

The inherent assumptions in the previous equations are listed below.

(1) The droplet is spherical.

(2) The drag forces on the droplet are independent of the state of the droplet (i.e., heating or evaporating).

(3) The drag on a droplet is independent of any other nearby droplet which may influence the droplet's motion.

For the case of closely spaced droplets, the drag coefficient is reduced, due to a "drafting" effect, causing one droplet traveling in the wake of its predecessor to encounter less resistance from the surrounding gases. However, the reduced drag coefficient actually acts only in the direction of droplet motion. This may not be in the direction of relative velocity (e.g., $u-u_\infty$), so that this modification is not simply a modification of C_D in Equations 3.2.4 through 3.2.6. These equations must be rewritten to account for a reduced drag in the direction of droplet motion, and not in the perpendicular direction. Denoting the direction of droplet motion with a subscript of 1 and the perpendicular direction with a subscript of 2, Equations 3.2.4 through 3.2.6 become:

$$\frac{\partial u}{\partial t} = \frac{3\rho_g}{4\rho_\ell D}\left[C_{D1}\ (u - u_\infty)_1^2 + C_{D2}\ (u - u_\infty)_2^2\right] - g_x \qquad 3.2.9$$

$$\frac{\partial v}{\partial t} = \frac{w^2}{y} - \frac{3\rho_g}{4\rho_\ell D}\left[C_{D1}\ (v - v_\infty)_1^2 + C_{D2}\ (v - v_\infty)_2^2\right] - g_y \qquad 3.2.10$$

$$\frac{\partial w}{\partial t} = \frac{-wv}{y} - \frac{3\rho_g}{4\rho_\ell D}\left[(C_{D1}\ (w - w_\infty)_1^2 + C_{D2}\ (w - w_\infty)_2^2\right] - g_z \qquad 3.2.11$$

In the limit, as the droplet's spacing approaches the droplet diameter, the drag coefficient may be assumed to approach the friction drag coefficient of a long rod. For a very long rod, the theory of Glauert and Lighthill[7] yields

$$C_{D\ ROD} = 0.755/Re \qquad 3.2.12$$

The drag coefficient of closely spaced spheres where L, the interdroplet spacing approaches D, the droplet diameter, was hypothesized by Mulholland et al.[8] to be

$$C_{D\ SPH} = C_{D\ ROD} + 34.8\ Re^{-1.009}(L/D - 1) \qquad 3.2.13$$

Finally, the form for the overall drag coefficient, for the regions between L/D → 1 and L/D → ∞, has been determined to be:

$$C_D{}^{-.707} = C_{D\ SPH}{}^{-.707} + C_{D\ ROD}{}^{-.707} \qquad 3.2.14$$

where the exponents and coefficients in equations 3.2.13 and 3.2.14 have been determined by Mulholland empirically.

The drag coefficient given in Equation 3.2.14 has been developed to account for the effect that closely spaced droplets will have on the drag coefficient. However, the drag on an evaporating droplet will be affected by the mass transfer rate from the surface. As a droplet evaporates, the fluid dynamics of the droplet are different than those of a non-evaporating droplet or solid sphere. The fluid which has evaporated enters the surrounding gases as a vapor trail, modifying the wake which in turn modifies the drag. Eisenklam et al.[2] have studied this effect and developed a formula for the relationship between the evaporation rate and the drag coefficient. The evaporation rate is represented by the transfer number, so that the affected drag coefficient, $C_D{*}$, can be written

$$C_D{*} = \frac{1}{(1+B)}\ C_D \qquad 3.2.15$$

where C_D is the drag coefficient of a solid sphere, and B is the transfer number, which is defined as follows:

$$B = \frac{C_{pg} (T_\infty - T)}{H_v} + \frac{Q (Yo^\infty / \sigma)}{H_v} \qquad 3.2.16$$

The first term describes the driving force of the temperature difference between the droplet and the surrounding environment and the second term describes the additional driving force for evaporation due to the droplet burning. In this equation, C_{pg} is the specific heat of the background gas, T_∞ is gas temperature, T is the droplet temperature, Q is the heating value of the fuel, Y_o^∞ is the mass fraction of oxygen in the background gas, H_v is the latent heat of vaporization of the fuel, and σ is the stoichiometric mass ratio of oxidizer to fuel. For a large mass transfer rate (due to a high temperature differential between droplet and environment), the transfer number is large, and the drag coefficient is reduced. The typical transfer number for a fuel droplet is between 2 and 5.

3.3 Droplet Heating

The droplet heating can be modeled by prescribing the rate of change of droplet temperature with time,

$$\frac{dT}{dt} = \frac{-6 \, Nu \, \lambda_g}{\rho_\ell D^2 \, C_{p\ell}} (T - T_\infty) \qquad 3.3.1$$

where T is the droplet temperature, Nu is the Nusselt number, λ_g is the thermal conductivity of the gas, and ρ_ℓ and $C_{p\ell}$ are droplet density and specific heat. The Nusselt number for a spherical droplet is calculated using the empirical relation of Ranz and Marshall,[9]

$$Nu = 2 + 0.6 \, Re^{0.5} \, Pr^{0.333} \qquad 3.3.2$$

where the Prandtl number, Pr, is

$$Pr = \frac{C_p \mu_g}{\lambda_g}.$$

If it is assumed that the Reynolds number is constant over a small time step, equation 3.3.1 can be integrated to give

$$\Delta T = T_\infty + (T_o - T_\infty) \exp\left[\frac{-6 \text{ Nu } \lambda_g}{\rho_\ell D^2 C_{p\ell}} (t - t_o)\right] \qquad 3.3.3$$

where T_o is the droplet temperature at time t_o. Once the droplet reaches the boiling point, it is assumed to remain at that temperature with further heat input causing evaporation. Even though the droplets are large, it is assumed that the thermal conductivity of the liquid fuel is sufficiently large to prevent internal temperature gradients. The impact of this assumption is to overestimate the time required for droplet heating to the boiling point. However, any errors introduced by this assumption would be partially offset by assuming no inner droplet circulation. (The Biot number is a parameter which represents the ratio of external convective forces to internal conductive forces. For the temperature ranges and fuels studied, the Biot number is less than one, verifying this assumption.)

The most significant assumptions employed here are:

(1) The droplet will not evaporate until it reaches its boiling point (i.e., before boiling, D is constant as T increases; at boiling, T is constant as D decreases).

(2) Reynolds number varies slowly with respect to time.

(3) Convection is the primary mode of heat transfer; heat transferred by conduction and radiation is minimal and can be neglected.

(4) The Nusselt number correlation is applicable for a non-evaporating sphere surrounded by gas. An evaporating sphere would be expected to have a different correlation for the Nusselt number.

3.4 Droplet Evaporation

For an isolated evaporating droplet, with no influence of other droplets on the evaporation rate, the decreasing size of the droplet can be expressed as

$$\left(\frac{dD}{dt}\right)_{iso} = \frac{-C_b}{2D}\left(1 + 0.23\ Re^{0.5}\right) \qquad 3.4.1$$

where C_b is an evaporation constant. C_b was derived from a quasi-steady state analysis of droplet combustion by Wise and Agoston:[10]

$$C_b = \frac{8\ \lambda_g}{\rho_\ell C p_g} \ln\ (1+B) \qquad 3.4.2$$

where B is the transfer number for evaporation.

The transfer number can be described as a ratio of the forces which cause evaporation to the forces which oppose evaporation, and is defined as

$$B = \frac{C_{pg}\ (T_\infty - T)}{H_v} + \frac{Q\ (Y_o{}^\infty/\sigma)}{H_v}. \qquad 3.4.3$$

Note that this is the same variable as was used to determine the drag coefficient, and is explained in more detail in Section 3.2.

Once the burning rate of an isolated droplet has been determined, the theory can be extended to cover an array of burning droplets. Many researchers have done work in this area, determining a connection between droplet spacing and evaporation rate. Labowsky[3] has postulated that the evaporation rate of an array of burning droplets can be expressed as the product of the burning rate of an isolated droplet and a burning rate correction factor, η_s. For a linear array, he has determined that

$$\eta_s = 1 - \frac{1}{\ell} + \frac{1}{\ell^2} \tag{3.4.4}$$

where ℓ is a dimensionless variable which is the ratio of droplet spacing and droplet radius.

Therefore, the effect of closely spaced droplets can be accounted for by the following equation:

$$\left(\frac{dD}{dt}\right) = \eta_s \left(\frac{dD}{dt}\right)^{iso} \tag{3.4.5}$$

During evaporation, if all quantities other than D change slowly over one timestep, Equation 3.4.1 can be integrated and combined with Equation 3.4.5 to give

$$D^2 = - \eta_s C_b \,(1 + 0.23\, Re^{0.5})\,\Delta t \tag{3.4.6}$$

In this development, it has been assumed that:

(1) The droplet consists of a single homogeneous material with a unique boiling point.

(2) The droplet is at a uniform and constant temperature during evaporation.

(3) Droplet evaporation occurs only at the droplet boiling point.

4.0 THEORY AND FORMULATION - FLOW FIELD SPECIFICATION

In order to predict a droplet's motion, heating and evaporation in an incinerator, the flow field must be specified. Various parameters to be examined include furnace geometry, velocity and temperature profiles within the furnace, and the composition of the flow field itself. In this section each of these areas will be addressed.

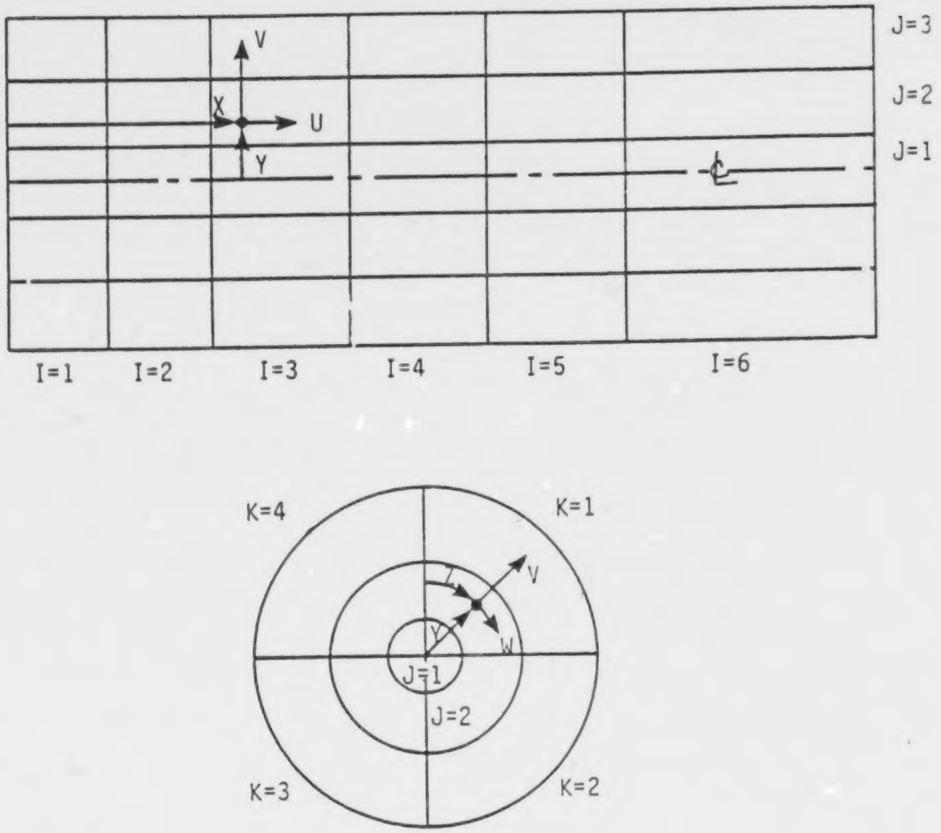
4.1 Geometry

The incinerator is assumed to be a circular cylinder divided into imaginary zones, shown in Figure 3. Note that the x-direction is axial, originating to the left of the horizontal cylinder. The y-direction originates at the centerline of the cylinder and increases in the radial direction. The z coordinate measures the tangential position, with its origin in the vertical position. Each zone can store temperature and density data, with velocity data being specified at the zone boundaries. The number of axial, radial and tangential zones are inputs to the model, as are the zone dimensions.

4.2 Velocity Profiles

The velocity within the incinerator is specified at the boundaries of each zone, and is assumed to be uniform along the boundary surface. Figure 4 shows the particular manner of specifying the velocities at each boundary. The velocity of the gas within a zone is determined by arithmetically averaging the velocity values at each zone boundary. In three dimensions, the tangential gas velocities are a function of radial position. One or more of the innermost radial zones may be specified to have a forced vortex velocity profile:

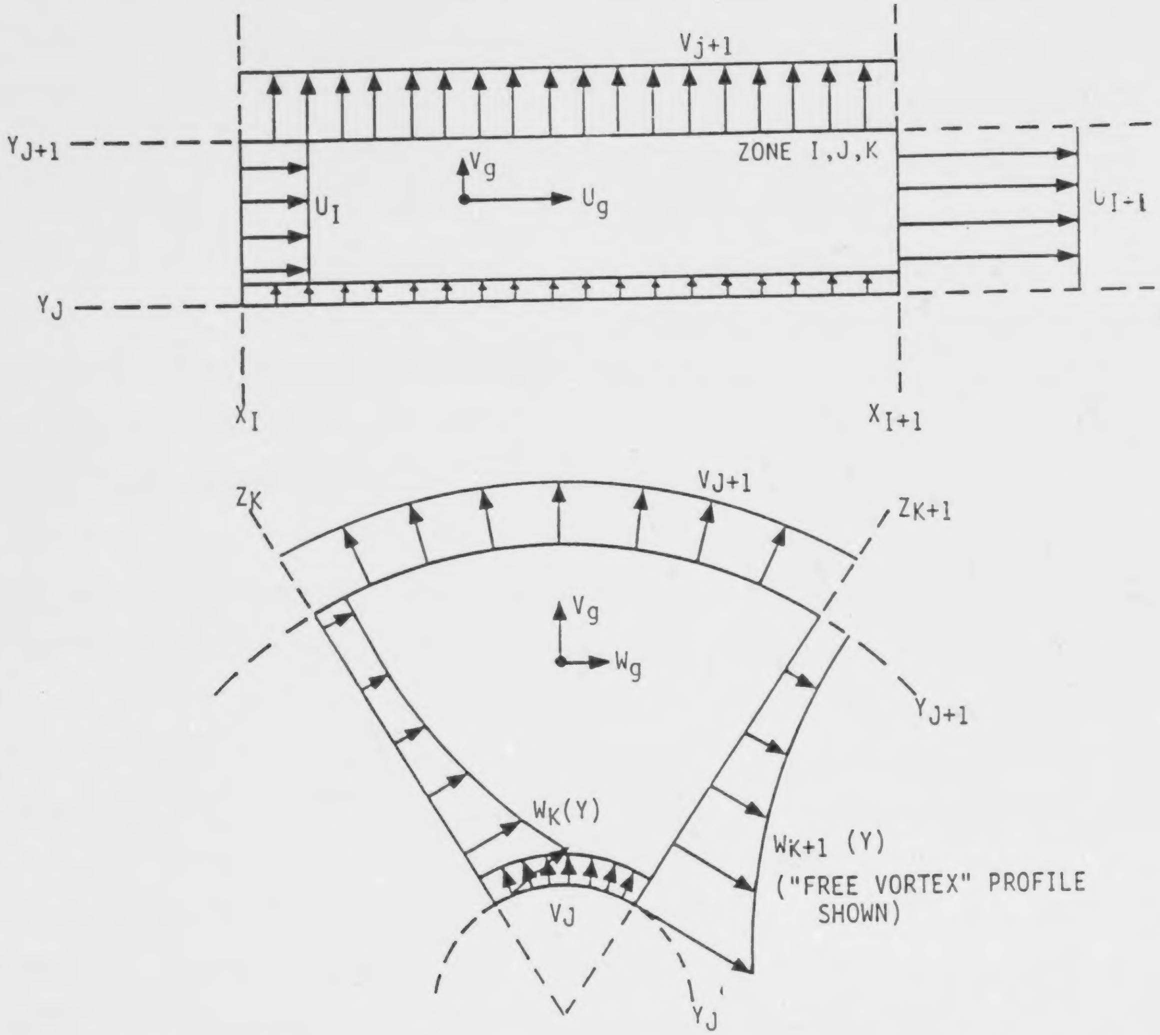
$$w_1 = \Omega y \tag{4.2.1}$$


J=3
J=2
J=1
V
X
U
Y
℄
I=1
I=2
I=3
I=4
I=5
I=6
K=4
K=1
V
Z
Y
W
J=1
J=2
K=3
K=2

NOMENCLATURE:

Component	Zone Index	Position	Linear Velocity
Axial	I	X (m)	U (m/s)
Radial	J	Y (m)	V (m/s)
Azimuthal	K	Z (deg)	W (m/s

Figure 3. Combustor geometry for liquid injection model



V_{j+1}
Y_{J+1}
ZONE I,J,K
V_g
U_g
U_I
U_{I+1}
Y_J
X_I
X_{I+1}
Z_K
V_{J+1}
Z_{K+1}
V_g
W_g
Y_{J+1}
$W_K(Y)$
W_{K+1} (Y)
("FREE VORTEX" PROFILE SHOWN)
V_J
Y_J

Local Gas Velocity Component:	Is Found By Interpolating With Respect To:	Interpolated Between Values:
U_g	X	U_I and U_{I+1}
V_g	Y	V_J and V_{J+1}
W_g	Z	$W_K(Y)$ and $W_{K+1}(Y)$

Figure 4. Gas Velocity Descriptions

The remaining outer radial zones are then assigned a free vortex velocity profile:

$$w_2 = \frac{\Gamma}{2\,\mu\,y} \qquad 4.2.2$$

In these equations, Ω is angular velocity and Γ is the circulation. In addition, any number of the outermost radial zones may be designated as boundary layers, in which the tangential velocity profile is modified to be:

$$w = (w_1 \text{ or } w_2) \left[\frac{R_o - y}{R_o - R_s} \right] \qquad 4.2.3$$

where R_o is the incinerator radius and R_s is the radial location of the inner edge of the boundary layer. Thus, w is calculated for each angular zone boundary.

As an option, the model allows for various simplified cases in which the specified velocities are not considered. The available options include

(1) Specifying a constant value for the axial velocity,

(2) Specifying a constant value for the radial velocity, and

(3) Specifying a swirl number which is used along with the inlet axial velocity to calculate the angular velocity. The tangential velocity, w, is calculated so that it is zero at the outlet and is continuous in y.

4.3 Turbulence

In practical combustor flow fields, the role of turbulent fluctuations plays an important part in the physical description of the droplet trajectories. As each droplet passes through the flow field, it is affected by its surroundings, including any variations in the gas velocity through which it travels. The impact of turbulence on droplet trajectory was clearly observed in the CRB in-house droplet experiments. Specifically, the location of droplet burnout was found to be over a relatively large volume rather than a discrete point.

When the baseline droplet model was exercised to simulate the CRB experiments, the predicted location of droplet burnout was in reasonable agreement with experimental observations. A paper on this experimental and theoretical effort was prepared and presented as a poster session at the Twenty-First Symposium (International) on Combustion in Munich, Germany in 1986.

For evaluation of how rogue hazardous waste droplets influence waste destruction efficiency it is essential to have a model with sufficient capability to predict the domain of droplet burnout. To achieve that goal, it is necessary to describe the turbulent characteristics of the background gas as well as its time mean properties. There are a wide variety of modeling approaches which could be employed. A decision was made to adopt a simple approach as a first attempt. In this instance, simple implies the minimum amount of required experimental data for code input. Specifically, the user is required to input experimental data (or an estimate) for the mean velocity at each grid location in the computational domain. In the experimental work performed by the CRB, the velocity was measured using a specially designed five hole pitot probe. Instantaneous measurements were taken, and the turbulent intensity was found to be fairly constant over a range of velocity values. The standard deviation of the velocity is therefore programmed into the code to reflect the experimental results. The following values are included in the May 1987 version of the code, where σ_x, σ_y and σ_z represent the standard deviations of the velocity in the axial, radial and tangential directions, respectively.

V_{mean} (m/s)	σ_x	σ_y	σ_z
< 7.62	1.5240	3.0480	1.5240
7.62-15.24	1.2192	1.8288	1.2192
> 15.24	0.6096	0.9144	0.6096

In the baseline model, the background gas velocity at any model point was defined as the input mean velocity. In the turbulent flow simulation, that background gas velocity is calculated by having a random number generator select an instantaneous velocity from the velocity probability distribution function defined by the time mean turbulence intensity and the Gaussian distribution. As a droplet passes through the flow field, it will experience local background gas velocities which vary in a random fashion. To define the domain of droplet burnout, the code tracks the trajectory of multiple individual droplets as they pass through the randomly fluctuating flow field.

It must be recognized that there are many uncertainties in how the turbulent velocity field should be specified. The instantaneous velocity at a single point will appear to fluctuate about a time mean. There is, however, significant evidence of large scale turbulent structures or eddies which maintain a coherent structure as they translate through the flow. Recognizing these uncertainties, three options have been developed to specify the turbulent velocity field.

The first and simplest approach is to assume that each mean velocity in the incinerator has the same fluctuation applied to it during a droplet lifetime. The rationale for assuming this is that it is possible that a droplet remains within a single turbulent eddy as it travels through the incinerator, maintaining a constant fluctuation velocity. In this case, if the "random" deviation is a large positive value, the droplet will travel through an environment with velocities higher than the mean velocities, and consequently penetrate farther into the incinerator. An opposite effect occurs if the turbulent fluctuation applied to each mean velocity is negative, and the penetration is adversely affected.

An alternate method for applying turbulent fluctuations to the gas velocity is to modify the velocity of each grid location individually. As the droplet proceeds from one grid to another, the fluctuation to the mean velocity changes. This modeling has the effect of assuming that turbulent eddies exist for the length of one grid spacing. Since the grid boundaries are arbitrarily imposed, this assumption could be an oversimplification to the modeling of the physical process, if care is not taken in selecting an appropriate grid size.

The third method for applying turbulence is based on the Prandtl mixing length as defined by classical turbulence theory. In this case the length scale for the turbulent fluctuation is translated to a time scale, during which a single fluctuation is applied. At the end of the given time period, a new fluctuation is determined and applied to the mean velocity of the current zone.

The approach which was employed in the final version of the code is the one which is described as the second method. Different turbulent fluctuations are applied to the velocity of each grid location, and in fact different fluctuations are applied to the three different velocity vectors—x, y, and z—in the same grid location. This provides for a greater degree of independence in the background gas velocities, so that a droplet traveling through the gas will not see a field in which the velocities are all skewed high or skewed low. As mentioned previously, it is assumed in this case that the turbulent fluctuations exist over a distance of one grid length. The user must take care when defining the grid that this is a reasonable assumption, and the grid size is on the same order of magnitude as the Prandtl mixing length.

4.4 Temperature Profiles

The temperature within the incinerator is also specified by means of an input file. The temperatures can be specified for each zone, or an overall default temperature can be set, forcing the entire field to be uniform. Since the density, thermal conductivity, specific heat and viscosity depend on the temperature and composition of the gas alone, constant temperature and uniform gas composition make these properties constant across the flow field.

4.5 Gas Properties

The properties which are used in this model include those which are necessary to specify the Reynolds number, the Prandtl number and the Nusselt number of each droplet moving through each zone. These include the density, thermal conductivity, viscosity and specific heat at constant pressure of the incinerator gas. The gas is assumed to be a mixture consisting of CO_2, H_2O, N_2, and O_2 in the amounts specified in an input file. Density is calculated using the ideal gas law, assuming a pressure of 1 atmosphere. The viscosity of each species is calculated from the Chapman-Enskog theory[11] and the mixture viscosity is calculated as a weighted sum of pure species viscosities, using the weighting function given by Brokaw.[12] The thermal conductivity of each species is calculated by the method of Bromley[13] and the mixture thermal conductivity is calculated by a weighted sum technique similar to that used for viscosity, using the Mason and Saxena modification.[14] Pure species specific heat is calculated for each gas species using the results of Sweigert and Beardsley,[15] divided by molecular weight to convert from a "per mole" to a "per mass" basis. The mixture specific heat is calculated by an average of the species specific heats weighted by mass fraction.[14] Most of the theories described above are summarized in the text The Properties of Gases and Liquids, by Reid, Prausnitz and Sherwood.[11]

5.0 NUMERICAL PROCEDURE

The motion, heating and evaporation of an individual droplet may be expressed in terms of ordinary differential equations, as described in Section 3. The equations of motion are solved using an explicit finite difference technique, and the equations of heating and evaporation are solved using analytical solutions which are valid for sufficiently short timesteps.

The finite difference equations solved here are unconditionally stable; however, the timestep size must be appropriate to produce accurate numerical estimates of the true analytical solutions to the differential equations. The timestep size must be short enough for the solutions to be accurate, yet not so short that many unnecessary calculations are performed, using excessive computational time. To estimate the size of a timestep, the following calculations are completed:

(1) The characteristic time constants for the solutions to the equations are estimated, then multiplied by a number between zero and one. The multiplier is included for greater accuracy, to ensure that the timestep will provide a good estimate to the solution of the equation.

(2) The time required to the particle to traverse a zone is estimated based on zone dimensions and particle velocity, and then is multiplied by a number between zero and one.

The above calculations are compared and the timestep size, Δt is determined to be the smallest estimated time value. This method of selecting Δt assures that the timestep size is less than the characteristic time for the solution to the differential equations, and is also short enough that the droplet history within each zone is calculated accurately. The multiplier, or "safety factor" is a value which is an input to the program and is a value between zero and one. This is included to simplify calculations and ensure numerical accuracy. (For a complete listing of all program inputs, refer to Appendix A, the User's Manual.)

Once the timestep is selected and the gas properties of each zone have been calculated, the numerical procedure for determining droplet trajectory begins. The first droplet is injected at a specified location into a corresponding zone in the combustor. A droplet Reynolds number is calculated based on the gas properties of the zone, the diameter of the droplet and the magnitude of its velocity relative to the background gas. A drag coefficient is chosen based on the Reynolds number and droplet spacing, and then integration begins. Equations of motion are updated using an explicit solution to a finite difference approximation in which each time derivative term is replaced by a forward time-difference. For Equation 3.2.1 this is

$$\frac{\partial x_p}{\partial t} = \frac{x_p(t + \Delta t) - x_p(t)}{\Delta t} \qquad 5.0.1$$

where $x_p(t)$ and $x_p(t + \Delta t)$ are the values of x_p at the beginning and end of a timestep, and Δt is the timestep size. This approximation may be substituted into the left hand side of Equation 3.2.1, where the quantities on the right hand side are evaluated at Δt. The equation may be solved for the dependent variable at the end of the timestep when the values at the beginning of the timestep are known. This same procedure is used to determine the remaining dependent variables of Equations 3.2.2 through 3.2.6.

The droplet temperature is determined from Equation 3.3.3, assuming that all quantities except the temperature itself have little variation over one timestep. The equation is solved analytically to find T at the end of the timestep in terms of quantities which are known at the start of the timestep.

If the droplet temperature reaches the liquid boiling temperature, the temperature remains constant and the program branches to the calculations of droplet diameter with evaporation. Equation 3.4.3 is solved analytically by assuming that all quantities except the diameter remain constant over one timestep. Each time Equation 3.4.3 is solved, the remaining droplet mass fraction is checked against a tolerance to determine if evaporation is complete.

The integration procedure continues, determining new values for the droplet's position, velocity, temperature and size, until the droplet reaches a zone boundary. At this point the droplet position is compared with the locations of the solid boundaries. If the zone boundary is not a solid wall boundary, the drop continues into the next zone, repeating the integration procedure. If the drop has collided upon a wall, the droplet will either evaporate or condense there. If the drop is already boiling or the wall is above the droplet boiling temperature, the drop will evaporate at the point of contact. If the drop is not boiling and the wall temperature is less than its boiling point, the drop will condense on the wall at the point of contact.

If turbulence in the flow field is being considered (as indicated by a flag in the data file), a number of drops will be injected with the same initial defining parameters. After the first droplet has either evaporated or collided with a combustor wall, the numerical procedure for another droplet begins. This injection-to-evaporation process continues as many times as has been specified by the user to obtain an envelope of droplet trajectory end-points. The program has the capability of examining any number of droplets with different initial parameters, such as diameter, velocity or spacing. When the calculations for one droplet are complete, new initial parameters are read for the next droplet, and the procedure begins again, continuing until all the sets of initial parameters have been run.

6.0 CODE ORGANIZATION

The two and three-dimensional versions of the computer code are organized in the same manner, with the two-dimensional version being essentially a simplified modification of the three-dimensional version. This section gives a brief description of the purpose of each segment of the code. Each source file consists of a main program and ten subroutines which are listed below for both versions. Figure 5 illustrates the relationship between the source files, data files and output files, as well as showing how the subroutines are interconnected.

	Two-Dimensional	Three-Dimensional
Source Filename:	DROP2D.FOR	DROP3D.FOR
Main Program:	DROPCIN	ICMINC
Subroutines:	INJECT	ICSINJ
	RANDOM	RANDOM
	SETINJ	ICSSET
	GPROP	ICSGAS
	DROP	ICSDRP
	SPRAY	ICSSPR
	DRPMOV	ICSMOV
	SETPRT	ICPSET
	GASPRT	ICPGAS
	DRPPRT	ICPSPR
	INJPRT	ICPINJ
Data Filename:	DROP2D.DAT	DROP3D.DAT

A complete User's Manual is provided in Appendix A for both versions, containing a listing of the data files, along with a list of the input variables, format specifications and variable description. Appendices B and C contain listings of the 2-D and 3-D codes, respectively. In the following description of the program segments, names within parentheses refer to the subroutines found in the 3-D version.

DROPCIN (ICMINC) is the main driver program for the model. It reads the input data to the program in order to define the case being analyzed. DROPCIN

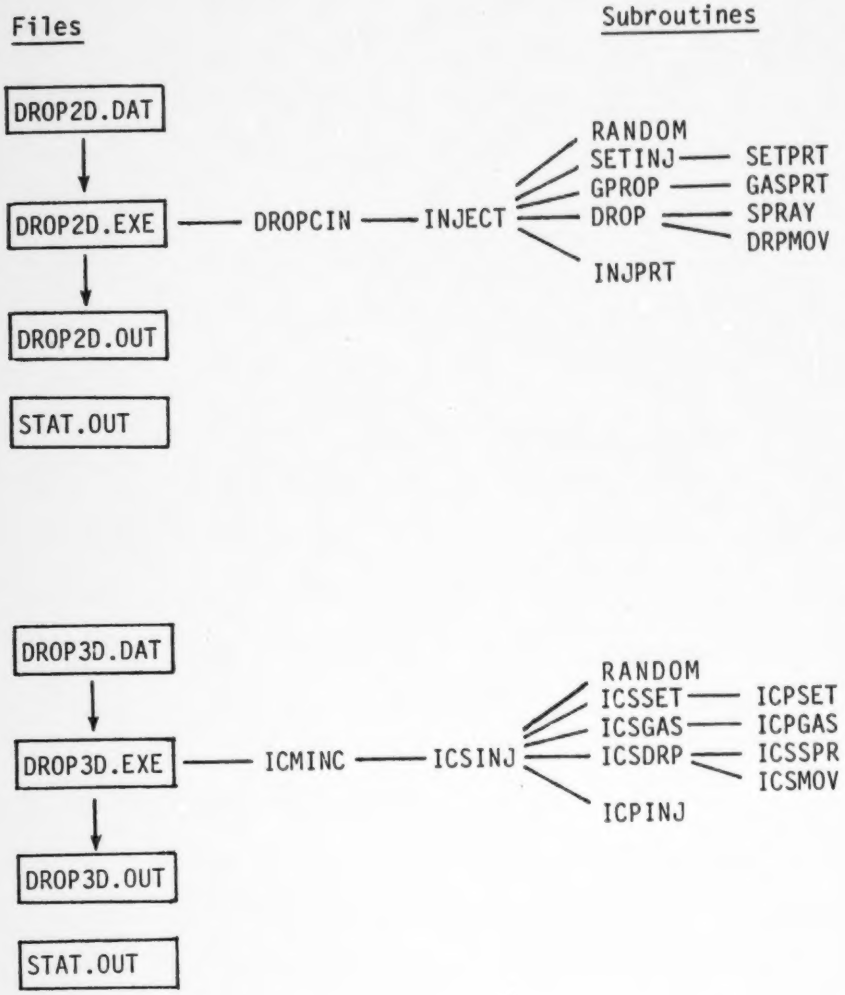

Files
Subroutines
DROP2D.DAT
DROP2D.EXE
DROP2D.OUT
STAT.OUT
DROPCIN
INJECT
RANDOM
SETINJ
SETPRT
GPROP
GASPRT
DROP
SPRAY
DRPMOV
INJPRT
DROP3D.DAT
DROP3D.EXE
DROP3D.OUT
STAT.OUT
ICMINC
ICSINJ
RANDOM
ICSSET
ICPSET
ICSGAS
ICPGAS
ICSDRP
ICSSPR
ICSMOV
ICPINJ

Figure 5. File and subroutine structure for two and three dimensional codes

(ICMINC) calls the subroutine INJECT (ICSINJ), in which the major calculations are performed.

Subroutine INJECT (ICSINJ) is the main subroutine for the droplet injection and evaporation code. It calls all of the other subroutines either directly or indirectly. The subroutines SETINJ (ICSSET) and GPROP (ICSGAS) are called to set the incinerator conditions and gas properties. Then RANDOM (RANDOM) is called if turbulence is to be imposed on the gas velocities. The subroutine DROP (ICSDRP) is called next to send the droplets through the incinerator. Finally, the results of the model are printed with the subroutines DRPPRT (ICPSPR) and INJPRT (ICPINJ).

Subroutine RANDOM (RANDOM) is essentially a number generator for Gaussian distribution. It contains a random number generator which is initiated by the internal computer clock. The random number is matched to a normal curve, so that a "random Gaussian" number is returned to INJECT (ICSINJ).

Subroutine SETINJ (ICSSET) calculates the initial data for the injection calculation excluding the gas properties. Then, incinerator conditions and parameters are read from an input file, as are parameters for timesteps through the incinerator. Options are included to set the wall and gas temperatures and the u and v velocities to constant dummy values or to use input temperature and velocity data. The coordinates of the x and y zone boundaries are determined, then the zone areas are calculated and the u and v velocity components are found at each zone boundary. Subroutine SETPRT (ICPSET) is called to print out the variables from this subroutine.

Subroutine GPROP (ICSGAS) is used to calculate the heat capacity, viscosity, and thermal conductivity of an ideal gas mixture of O_2, N_2, H_2O, and CO_2. The primary reference used is The Properties of Gases and Liquids, 3rd ed., by Reid, Prausnitz and Sherwood[11] (1977). Data are read for the molecular parameters and mass fraction. Normalization is checked and mole fractions are determined. The three properties of the pure components are determined, and the final gas properties are determined by taking weighted averages of them. Subroutine GASPRT (ICPGAS) is called to print out the gaseous properties for each zone.

Subroutine DROP (ICSDRP) takes a droplet zone by zone through the entire field. SPRAY (ICSSPR) is called to give initial conditions to each droplet. Gas velocities are initialized, then the stepping through the zones begins. Constants for each timestep are calculated (such as Re, Pr, and Nu) and the timestep size is determined. The droplet's motion, heating and evaporation is calculated with DRPMOV (ICSMOV). When the droplet reaches the end of one zone, if it has not evaporated and is not on a solid wall boundary, a new zone is entered and the procedure for each zone is repeated. A warning message is displayed when the droplet is considered evaporated, or if all zones have been visited and the droplet has not evaporated.

The initial conditions for each droplet are assigned in subroutine SPRAY (ICSSPR), being read from a data file. The initial zone is located based on the boundaries of the system, and the initial gas velocity is specified. An optional printout of the droplet data is provided through DRPPRT (ICPSPR).

Subroutine DRPMOV (ICSMOV) calculates the motion, heating and evaporation of a single droplet during a single timestep. New drop positions, velocities and temperatures are calculated, taking into consideration whether or not the droplet is boiling.

SETPRT (ICPSET) is a subroutine which prints variables from the main program and subroutine SETINJ (ICSSET).

GASPRT (ICSGAS) is a subroutine which prints the important input and output values of GPROP (ICSGAS). GASPRT (ICPGAS) is called from GPROP (ICSGAS).

DRPPRT (ICPSPR) is a subroutine which prints variables from subroutines DROP (ICSDRP) and SPRAY (ICSSPR). DRPPRT (ICPSPR) is called from subroutine SPRAY (ICSSPR).

INJPRT (ICPINJ) is a subroutine which prints the final results of the subroutine INJECT (ICSINJ). INJPRT (ICPINJ) is called from INJECT (ICSINJ).

There is one file which contains input data to the two-dimensional droplet evaporation model, named DROP2D.DAT. It provides the furnace conditions and geometry, the case title, and other overall information; defines the specific droplet properties of the given gas, as well as defining some printout flags; and specifies the droplet initial conditions. This file may contain as many different droplet specifications as desired. The three-dimensional version also uses one data file named DROP3D.DAT. Additional information necessary to define the third dimension is included in this file. There are two output files. The output files DROP2D.OUT and DROP3D.OUT contain the information which was specified to be printed in terms of input values, gas properties, and a listing of the droplet trajectories. The final statistical summary for turbulent predictions is directed into the file STAT.OUT. A sample of the output files are given in Appendix D.

7.0 USER FRIENDLY INPUT GENERATION CODE

A user friendly code has been written which allows the user to interactively modify the data files for two and three-dimensional versions of the droplet injection code. As described in the introduction, this code is written for the IBM PC/AT, and will modify the existing data files for the two and three dimensional versions. The user friendly code, named CHDAT (Change Data), takes the user step by step through a modification sequence with menus and display screens. A listing of the code CHDAT is given in Appendix E. It should be noted that the use of this code is optional, and the user may wish to modify the data files "manually" using an available editor. A description of the meaning and format of each input variable is provided in Appendix A, the User's Manual.

8.0 MODEL CAPABILITY

The model is capable of predicting the complete history of a droplet's position, velocity and temperature. Ranges for basic input parameters of the 2-D and 3-D versions are shown below:

Input Parameters	2D	3D
Furnace Size	no limit	no limit
Number of Axial Zones	1-10	1-25
Number of Radial Zones	1-5	1-15
Number of Circumferential Zones	N/A	1-5
Components of Background Gas (N_2,O_2,H_2O,CO_2)	0-100% each (but sum must be 100%)	0-100% each
Temperature (K)	300-2777	300-2777

The output of the model includes a list of input parameters, corresponding gas properties, and a projection of the position, velocity, temperature, and degree of evaporation of each droplet which is injected into the furnace.

Several model runs may be required to fully analyze the combined effects of individual input conditions. The effects of variations in input values can be assessed individually or the cumulative effect can be assessed by varying several conditions simultaneously.

9.0 POSSIBLE CODE ENHANCEMENTS

The preliminary version of this model of the trajectory heating and evaporation of a droplet in an incinerator contains all the formulations described in this user's manual. However, the model contains assumptions and simplifications which cause it to be a less than exact representation of the actual physical processes of droplet motion, heating and evaporation. Some assumptions are necessary to reduce the equations to a manageable form which can be solved with an appropriate numerical technique. Others were made in order to simplify the equations and make the code operational. Therefore, some additions and corrections are possible which would relax some of the assumptions, in order to obtain a more correct representation of the physical situation. This section describes some of the inherent assumptions within the code and possible modifications to relax them.

9.1 Group Combustion

Assumption: The droplets travel through the flow field as isolated droplets, unaffected by interaction with any other droplets.

Modification: Various modifications may be implemented to account for droplet interaction under combustion conditions (a burning droplet). Raising the droplet boiling temperature is one simple approach to simulate this interaction. Another possibility is to modify the formulation for evaporation by changing C_b. The empirical relation for the Nusselt number was determined for an isolated sphere; another relation could be used to describe the heating effect for a droplet cloud. Changing stoichiometry of the gas surrounding a burning droplet could have a marked effect on the droplet's burning rate, and this should also be considered as an approach to modeling group combustion. Finally, in modeling a dense spray, the aspect of droplet collision must also be addressed.

9.2 Droplet Composition

Assumption: Each droplet is of uniform composition, and liquid properties are independent of temperature.

Modification: In practical hazardous waste incinerators, waste is often mixed with an organic fuel. The effect of multicomponent droplets on liquid properties and evaporation warrants further attention. Also, liquid properties (notably specific heat) are temperature dependent. Approximations for temperature dependencies of liquid properties can be included in future versions of the model for better consistency with the temperature dependent calculations of gas properties.

9.3 Droplet Evaporation

Assumption: All evaporation occurs after the droplet has reached its boiling point.

Modification: It is possible that a significant portion of droplet evaporation occurs before the droplet reaches its boiling point, since the time for droplet heating is significant compared to the total droplet lifetime. Calculation of evaporation would proceed from initial droplet injection rather than from the droplet boiling point. Alternately, some fuels (such as No. 2 fuel oil) have a variable boiling point. Boiling initiates at one temperature and continues to boil as the temperature rises. In either case, the analytical heat and mass balance equations should be modified accordingly. Simultaneous solutions of droplet heating and evaporation would cause the analytical solution to the evaporation equation to be invalid; thus, a finite difference or Runge Kutta method could be used to solve the equations.

10.0 COMPARISON OF EXPERIMENTAL RESULTS WITH NUMERICAL PREDICTIONS

For widely spaced droplets, the predicted location at which the droplet is completely evaporated is compared to the experimentally measured range of droplet penetrations in Table 1 (page 3). Figure 1 (pages 4-5) shows the comparison graphically, displaying a top view and an end view of the experimental and numerically predicted trajectories. Bounds on the experimental ranges at each test condition are given by the position of earliest droplet ignition and farthest droplet burnout. The model predicts a mean evaporation point.

In most tests, the model predicts an axial penetration near the experimental ignition point, thus predicting the minimum axial penetration distance. The trends of the experimental measurements are closely followed by those of the computer model. Doubling the initial droplet velocity approximately doubles the axial penetration. Increasing droplet size also increases the axial penetration.

The model predictions for testing variable grid space size also followed the trends of the experimental results, although the model showed less of a dependence on spacing than did the experiments. The axial penetration from these tests decreased with increased spacing, except for the ignition location of test point 6. This trend is to be expected, since more space between the droplets provides a better opportunity for drag forces to affect the trajectory. The model predictions are consistent with this; however, there is only a 17.6 percent increase between the most closely spaced droplets and the nominal case, whereas the experimental value show a 133 percent increase between these cases at the ignition point.

The test for an injection angle of 45 degrees (test point 13), instead of the nominal 30 degrees, is the only point which differs from the experimental trends. The model predicts that the axial penetration is less than that of the nominal case whereas the experiments show that the droplet penetration in this case is greater.

Unexpected results were obtained from model predictions of radial endpoints in all cases. Whereas the experimental results showed the endpoints to be approximately between 8 and 15 cm from the centerline for the nominal case, the model predicted 2.9 cm. It should be noted that the injection location was 14 cm from the center of the combustor and the droplets were injected toward the centerline at a 30° angle. The experimental trajectories show that the droplets travel toward the center and then away from the center for a final ignition point of r=8 cm. The model predictions show that the droplet continues to move towards the center with an endpoint at r=2.9 cm. Apparently, the inward motion of the droplet in the experimental setup is overcome by the external forces of gravity and drag (from a gas velocity in the opposite direction) which causes the droplet to move outward, but the model does not show the same effect.

Overall, the model predictions correspond to the experimental measurements to a fair degree. Underprediction has been attributed to uncertainty in the velocity field, the inherent assumptions in the code, or an incomplete model of the effects of droplet spacing on the drag forces and evaporation.

11.0 CONCLUSIONS

A series of computer codes have been developed and delivered to EPA for use in analysis of CRB in-house droplet trajectory experiments, in accordance with Task 1 of the Fundamental Combustion Research program (FCR III). The motion, heating and evaporation of a single droplet in a combustor flow field can be predicted. There are two versions of the code which exist to predict the droplet's history in either two or three dimensions. A third code has also been developed, which is an interactive program to modify existing data files. The codes have been specially adapted to facilitate analysis of the CRB experimental setup. Distribution of the code to the general public would require modification or expansion of the input parameter options.

The original basis for program logic was the droplet code developed by Ayers et al. from University of Sheffield.[1] Major enhancements to the code include procedures accounting for the influence of droplet-to-droplet spacing on the drag coefficient and on evaporation rate. Also added were procedures to account for the influence of a burning droplet as opposed to a non-burning droplet on evaporation rate, and for turbulence in the background gas.

The three-dimensional code was run at various test conditions to predict droplet trajectory and penetration. Comparing these predictions with experimental results showed a fair degree of agreement in most cases. The model predicts penetration to a point which is close to the experimentally observed ignition point. However, the model does underestimate the penetration of the droplets when they are closely spaced.

This model allows the user to predict droplet trajectories within an incinerator at a variety of conditions. It can be integrated into a more complex spray flame code to evaluate the phenomena of droplet bypassing and penetration of the flame zone. Application includes prediction of hazardous waste incinerator failure modes and combustion pollutant emissions.

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APPENDIX A - USER'S MANUAL - LISTING AND DESCRIPTION OF INPUT VARIABLES

1.0 INTRODUCTION

DROP2D and DROP3D are computer programs which predict the motion, heating and evaporation of individual liquid droplets within a hazardous waste incinerator. The software was developed by Energy and Environmental Research Corporation (EER) under sponsorship of the Combustion Research Branch of the U.S. Environmental Protection Agency. This document is the User's Manual for the May 1987 version of the codes which have been supplied to EPA by EER. Delivery of the codes and User's Manual to EPA mark the completion of Task 1 under the Fundamental Combustion Research (FCR) program. The following sections are contained in this manual:

1) Introduction - which discusses the principles and limitations of the current version.
2) Setup - which lists the hardware and software requirements, and describes how to prepare a system to run DROP2D or DROP3D.
3) Use - which describes the use of the code and associated data and output files.
4) Data Files - which describes the input variables to the code.

1.1 Principles of Operation

The trajectory predictions are based on standard mechanics. The droplet history is determined from injection into the furnace until it has evaporated or until the droplet hits a wall. The incinerator size and operating conditions are specified, along with the droplet properties and initial conditions. The properties of the background gas - such as viscosity, density, specific heat and thermal conductivity - are calculated based on incinerator temperatures. Then the droplet characteristics are calculated as it proceeds through the incinerator, providing a history of the velocity, temperature and diameter at various locations.

The inputs to the code include definition of the incinerator geometry, temperature, velocities in three dimensions, and background gas composition. The droplet properties such as latent heat of vaporization, specific heat, boiling point and heat of combustion must be specified as well. Finally, droplet initial conditions must be provided, including initial diameter, velocity, injection location and temperature. A user-friendly interactive program exists (CHDAT) to assist users in preparing the data file.

The motion, heating, and evaporation of an individual droplet may be expressed in terms of ordinary differential equations. The equations of motion are solved using an explicit finite difference technique, and the equations of heating and evaporation are solved using analytical solutions which are valid for sufficiently short timesteps. For more details on the equations and computational procedure, refer to the report titled "Mathematical Modeling of Single Droplet Trajectories in Combustor Flow Fields."

The equations of motion are written considering drag and gravity to be the only external forces. The drag coefficient is calculated based on droplet spacing, evaporation rate and Reynolds number. The velocity field through which the droplet travels is a turbulent one, with randomly varying magnitudes based on a mean velocity and standard deviation for the fluctuating components.

In this model the equations for droplet heating and evaporation have been decoupled to control two separate phases in the droplet's lifetime. In the first phase, forced convection is assumed to be the only mode of heat transfer, with no evaporation occurring before boiling. After having reached the boiling point, the droplet temperature remains constant with further heat input causing evaporation. Evaporation is driven both by a temperature differential between the droplet and surrounding gas and by the heat generated in the burning process.

There are two versions of the program which exist for projections in two and three-dimensional space. The two dimensional version is a simplification of the three dimensional version, and uses the same calculation method, as described above. The program is written in Fortran, stored on a 360 Kbyte diskette, and typically runs on an IBM PC with 256 or 512 Kbytes of memory. The total computational time for the 3-dimensional version on an IBM PC/AT is 24.8 seconds for initial calculation plus approximately 50 seconds for the history of each drop.

Limitations of the Current Version

The May 1987 version of the program for predicting the motion, heating and evaporation of a single droplet is subject to the following limitations:

1) It will predict the injection of only one droplet at a time and does not consider the interaction between droplets.

2) It tends to underpredict the penetration of droplets which are closely spaced.

3) It requires the knowledge of the velocity and temperature fields of the incinerator gases and the equilibrium concentrations of CO, H_2O, N_2 and O_2, unless a constant temperature or velocity field can be assumed.

2.0 SETUP

In order to run DROP3D, the required hardware includes an IBM PC compatible computer with:

- at least 256 Kbytes of memory,
- a floppy disk drive capable of reading 360 Kbytes, double sided, double density floppy disks,
- a math coprocessor, and
- a monochrome or color monitor.

In addition to the required hardware, a printer is recommended for hard copy output and a hard disk drive would provide speedier input/output operations.

The software has been designed to run on DOS 3.1, however, it will probably run on other versions of DOS. The software is provided on a floppy diskette entitled "DROPLET - May '87" which contains the files listed below.

- DROP2D.EXE	calculates the trajectory of a droplet in two-dimensional space
- DROP3D.EXE	calculates the trajectory of a droplet in three-dimensional space
- DROP2D.DAT	is the data file for DROP2D.EXE
- DROP3D.DAT	is the data file for DROP3D.EXE
- CHDAT.EXE	prepares the input data files called by either the two or three-dimensional programs.

The following procedure should be used when preparing a system to run this code for the first time:

1) Review the given hardware and software requirements
2) Boot the system on DOS
3) Make a copy of the original diskette, using the copy for daily use and saving the original for a backup.

3.0 USE

There are two main programs for running the droplet model and one other one for preparing the input data file. The use of the codes is quite simple, requiring minimal effort or time by the user. The preparation of the data file is described in the next section. It can be done with the program CHDAT, or with any editor the user may have access to. In order to facilitate the modification of the input files, the user should be aware of which variables he wants to change. Once the data file is prepared, the executable file is run by typing either "DROP2D" or "DROP3D." When the program has run, two output files exist which contain the results from the runs, providing full trajectories of the droplets as well as a statistical summary of the droplet burnout points. The output files are named "DROP2D.OUT" or "DROP3D.OUT" for the two and three-dimensional versions respectively, with the statistical summary in "STAT.OUT."

4.0 DATA FILES

Since the droplet trajectory code can be run in either the two or three-dimensional version, there must be a corresponding data file for each version. The data files are named DROP2D.DAT and DROP3D.DAT for the two and three-dimensional versions, respectively. Because the 2-D version is just a simplified modification of the 3-D code, the data files are essentially the same with a few less entries in the simplified 2-D case. Table A1 provides a list of the variables which are included in the data files, with asterisks marking the variables which are not included in the 2-D version. It must also be noted that the arrays for the velocity and temperature in the 2-D case are 2 element arrays as opposed to 3 element arrays, as listed in the table.

The data files can be modified in one of two ways. The user may choose to use the editor which is available on the PC and modify the files himself. If this is done, the user must be certain to use the correct format for each entry. The proper format has been given in Table A1, although if the existing data files are used as a guide, there should be no problem in modifying the files.

The second option is for the user to run the code CHDAT which is an interactive, user-friendly code to change selected data values. The code is menu driven and provides the user with the choice of changing the data for either the 2-D or the 3-D case. The four main menus are shown in Figures A1, A-1 through A-4, and can facilitate changes to incinerator geometry and gas characteristics, operating parameters, and droplet initial conditions. Within each menu there are opportunities to make as many changes as desired before proceeding to the next menu. The program modifies the existing data file to be consistent with the input requirements of whichever version is being used.

TABLE A-1. MODEL INPUT VARIABLE DEFINITIONS

Variable	Format	Description	Unit or Value
CASE	A60	Case identification - this field may contain up to 60 characters.	
IX	I4	Number of axial zones.	
IY	I4	Number of radial zones.	
*IZ	I4	Number of circumferential zones.	
R(I)	F8.4	Array of the outer radial boundary of each zone. Up to five values can be read from one line. Program will expect IY entries.	m
XL(I)	F8.4	Array of the downstream axial boundary of each zone. Up to five values can be read from one line. Program will expect IX entries.	m
*DTHETA(I)	F8.4	Array of angular boundaries of each zone.	degrees kg/m^3
MDOTIN	F8.4	Total mass flow rate.	
FCO2	F8.5	Mass fraction of CO_2 in furnace at equilibrium.	
FH2O	F8.5	Mass fraction of H_2O in furnace at equilibrium.	
FN2	F8.5	Mass fraction of N_2 in furnace at equilibrium.	
FO2	F8.5	Mass fraction of O_2 in furnace at equilibrium.	
LABEL	A70	Label defining axial velocities.	
UBDY(I,J,K)	F8.4	Axial velocity at upstream boundary of zone I,J,K. Array is entered by varying J from 1 to IY, then varying I from 1 to IX, then varying K from 1 to IZ. Up to eight values can be read from one line.	m/s

Variable	Format	Description	Unit or Value
LABEL	A70	Label defining radial velocities.	
VBDY(I,J,K)	F8.4	Radial velocity at inner boundary of zone I,J,K. Array is read in the same manner as for UBDY(I,J,K)	m/s
*LABEL	A70	Label defining tangential velocities	
*WBDY(I,J,K)	F8.4	Circumferential velocity at counterclockwise boundary. Array is read in same manner as for UBDY (I,J,K).	m/s
LABEL	A70	Label defining gas temperatures.	
TEMP(I,J,K)	F8.2	Gas temperature in each zone. Array is read in same manner as for UBDY(I,J,K).	K
INCASE	A70	Label defining droplet fuel composition.	
TBOIL	F10.4	Temperature at which droplet will boil.	K
TLIQ	F10.4	Temperature at which droplet is injected.	K
CPLIQ	F10.4	Specific heat of liquid fuel.	m^2/s^2K
LHELIQ	E10.3	Latent heat of vaporization of fuel.	m^2/s^2
HCOMLQ	E10.3	Heating value of the fuel.	m^2/s^2
RHOLIQ	F10.4	Density of fuel at injection temperature.	kg/m^3
XNOZ	F10.4	Axial position of droplet injection.	m
YNOZ	F10.4	Radial position of droplet injection.	m
*ZNOZ	F10.4	Circumferential position of droplet injection.	m
NOZDIA	E10.3	Nozzle diameter - if negative this variable is neglected.	m

Variable	Format	Description	Unit or Value
AFMRAT	F10.4	Oxygen/fuel ratio - mass basis.	
ZSAFE DSAFE TSAFE ESAFE	F10.4	Safety factor - these numbers are multiplied by the projected timestep length to ensure continuous functions. The recommended value is 0.2.	
TOL1	F10.4	Tolerance for velocity - Drop calculations stop when droplet velocity is within this tolerance of the gas velocity.	
NRAMP	I10	Number of steps timestep is increased at beginning of zone.	
MAXSTP	I10	Maximum number of steps in one zone. If this number is exceeded, program will terminate.	
NDROP	I10	Number of drops injected with different spacing, velocity or diameter.	
NPRT1	I10	Printout every integration step up to this step number which occur in one zone.	
NPRT2	I10	Printout every integration step which is a multiple of this number.	
NPRT3	I10	If turbulence is used, this is the number of full droplet trajectories to be printed.	
INJOUT(1)	I10	Printout of properties of background gas.	
		No Print	0
		Print	1
INJOUT(2)	I10	Printout of incinerator conditions.	
		No Print	0
		Print	1
INJOUT(3)	I10	Printout of droplet trajectory.	
		No Print	0
		Print	1

Variable	Format	Description	Unit or Value
INJOUT(4)	I10	Printout of statistics file for turbulent runs. No Print Print	 0 1
INJOUT(5)	I10	Allowance for direction of gravity force. Gravity acts in radial direction Gravity acts in axial direction	 0 1
INJOUT(6)	I10	Not currently in use.	
INPTYP(1)	I10	Flag for wall temperature. TWALL set to input temperatures TWALL set to TWDUM	 0 1
INPTYP(2)	I10	Flag for gas temperatures. Gas temperatures set to input temperatures Gas temperatures all set to TGDUM	 0 1
INPTYP(3)	I10	Flag for axial velocities. Axial gas velocities set to input values Axial gas velocities all set to UDUM	 0 1
INPTYP(4)	I10	Flag for radial velocities. radial velocities set to input values radial velocities all set to VDUM	 0 1
INPTYP(5)	I10	Flag for tangential velocities. Tangential velocities set to input values Tangential velocities set by using the variable SWIRL	 0 1
INPTYP(6)	I10	Flag for turbulence. Turbulence No turbulence	 0 1
TWDUM	F10.4	Dummy wall temperature - used if INPTYP(1)=1.	°K
TGDUM	F10.4	Dummy gas temperature - used if INPTYP(2)=1.	°K
UDUM	F10.4	Dummy axial velocity - used if INPTYP(3)=1.	m/s
VDUM	F10.4	Dummy radial velocity - used if INPTYP(4)=1.	m/s

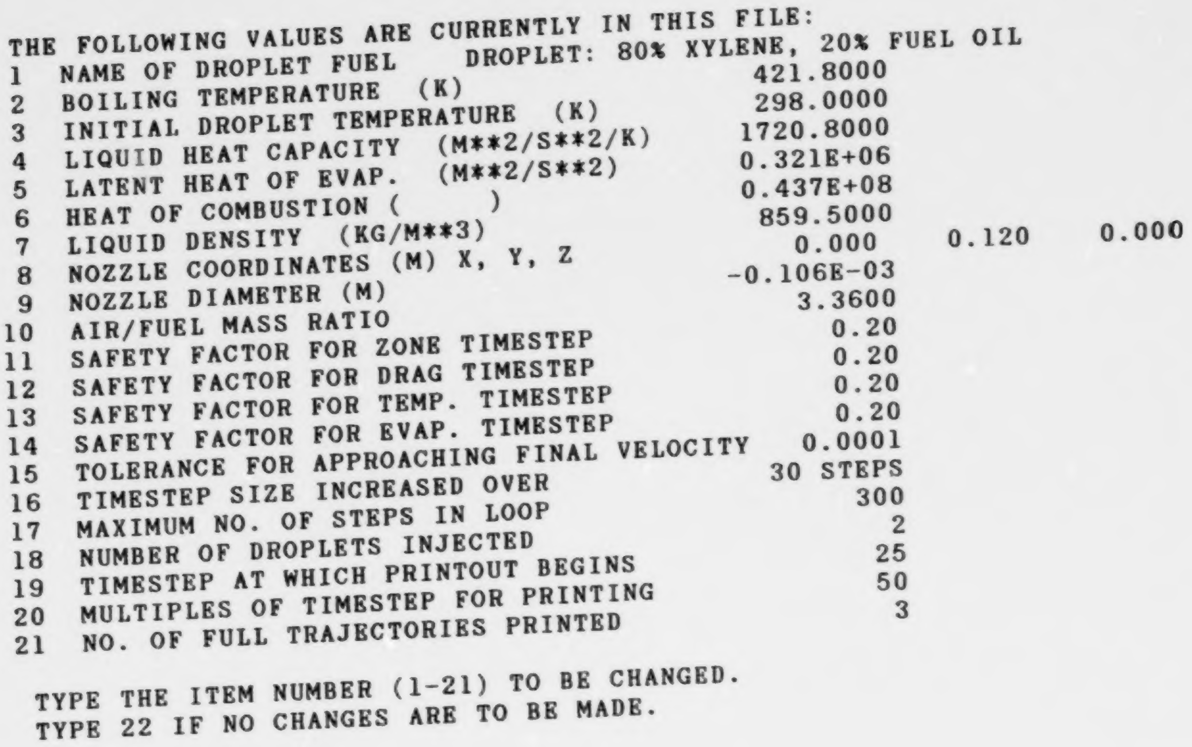
Variable	Format	Description	Unit or Value
*SWIRL	F10.4	Swirl number of furnace.	
*TOTLEN	F10.4	Total length of furnace.	m
*JLAYER	I10	Number of radial zones which make up the boundary layers.	
*JFORCE	I10	Number of radial zones which have forced vortex velocity profile.	
TIMAX	I10	Number of turbulent runs using the same droplet initial conditions.	
DINIT	E10.3	Initial droplet diameter.	m
DRPVEL	F10.4	Initial droplet velocity.	m/s
XPCOMP	F10.4	Component of velocity in axial direction (range is 0-1).	
YPCOMP	F10.4	Component of velocity in radial direction.	
*ZPCOMP	F10.4	Component of velocity in tangential direction.	
LOD	E10.3	Initial droplet spacing in terms of L/D.	

```
THE INFORMATION FOR THE CASE TO BE ANALYZED IS
GIVEN BELOW. CASE TITLE:  TYPE C FLAME - NUMERICAL PREDICTIONS


     1  CASE NAME
     2  NUMBER OF AXIAL ZONES
     3  NUMBER OF RADIAL ZONES
     4  NUMBER OF TANGENTIAL DIVISIONS
     5  AXIAL LENGTHS OF ZONE BOUNDARIES
     6  RADIAL LOCATIONS OF ZONE BOUNDARIES
     7  ANGULAR MEASUREMENTS OF EACH ZONE
     8  TOTAL MASS FLOW RATE
     9  MASS FRACTIONS OF CO2,H2O,N2,O2
    10  RELATIVE INPUT VELOCITIES
    11  GAS TEMPERATURES


TYPE THE NUMBER OF THE VALUE TO BE CHANGED.
IF NO CHANGES ARE TO BE MADE TYPE 12.
```

Figure A-1. Screen 1. Incinerator specification.



```
THE FOLLOWING VALUES ARE CURRENTLY IN THIS FILE:
1  NAME OF DROPLET FUEL    DROPLET: 80% XYLENE, 20% FUEL OIL
2  BOILING TEMPERATURE  (K)                  421.8000
3  INITIAL DROPLET TEMPERATURE  (K)          298.0000
4  LIQUID HEAT CAPACITY  (M**2/S**2/K)      1720.8000
5  LATENT HEAT OF EVAP.  (M**2/S**2)        0.321E+06
6  HEAT OF COMBUSTION (      )              0.437E+08
7  LIQUID DENSITY  (KG/M**3)                 859.5000
8  NOZZLE COORDINATES (M) X, Y, Z              0.000     0.120     0.000
9  NOZZLE DIAMETER (M)                      -0.106E-03
10  AIR/FUEL MASS RATIO                         3.3600
11  SAFETY FACTOR FOR ZONE TIMESTEP               0.20
12  SAFETY FACTOR FOR DRAG TIMESTEP               0.20
13  SAFETY FACTOR FOR TEMP. TIMESTEP              0.20
14  SAFETY FACTOR FOR EVAP. TIMESTEP              0.20
15  TOLERANCE FOR APPROACHING FINAL VELOCITY    0.0001
16  TIMESTEP SIZE INCREASED OVER              30 STEPS
17  MAXIMUM NO. OF STEPS IN LOOP                   300
18  NUMBER OF DROPLETS INJECTED                      2
19  TIMESTEP AT WHICH PRINTOUT BEGINS               25
20  MULTIPLES OF TIMESTEP FOR PRINTING              50
21  NO. OF FULL TRAJECTORIES PRINTED                 3

 TYPE THE ITEM NUMBER (1-21) TO BE CHANGED.
 TYPE 22 IF NO CHANGES ARE TO BE MADE.
```

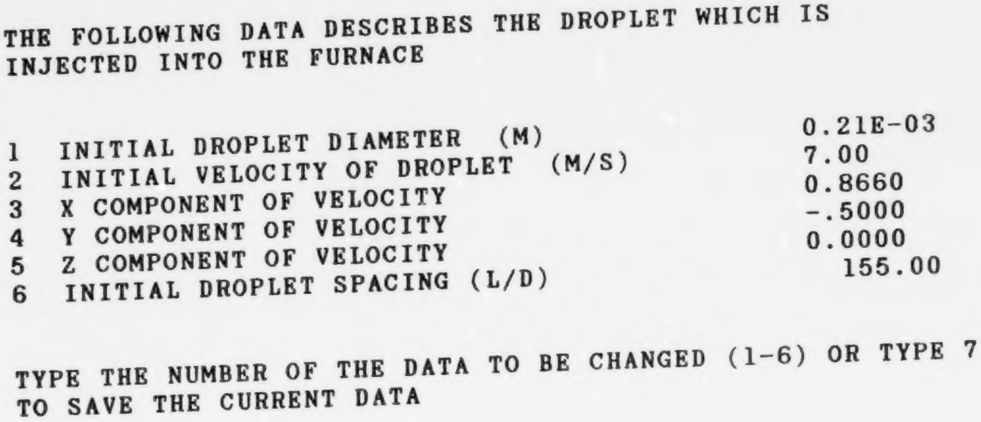
Figure A-2. Screen 2. Droplet properties.

```
THE FOLLOWING VALUES ARE CURRENTLY IN THIS FILE:

 1  GAS PROPERTIES PRINTED IF = 1                  0
 2  INCIN. PROP. PRINTED IF = 1                    0
 3  DROP OUTPUT PRINTED IF = 1                     1
 4  FINAL SUMMARY PRINTED IF = 1                   1
 5  TURNS ON GRAVITY IF = 1                        0
 6  DUMMY TWALL IS READ IF = 1                     0
 7  DUMMY GAS TEMP. USED IF = 1                    0
 8  DUMMY X VELOCITY USED IF = 1                   0
 9  DUMMY Y VELOCITY USED IF = 1                   0
10  TANG. VELOCITY SET WITH SWIRL IF = 1           0
11  TURBULENCE IS NOT USED IF = 1                  0
12  DUMMY WALL TEMPERATURE  (K)               298.00
13  DUMMY GAS TEMPERATURE  (K)                300.00
14  DUMMY X VELOCITY                            0.00
15  DUMMY Y VELOCITY                            2.20
16  SWIRL NUMBER                                0.0
17  TOTAL FURNACE LENGTH  (M)                   0.914
18  NO. OF INNER ZONES FOR BOUNDARY LAYER       0
19  NO. OF OUTER ZONES FOR FORCED VORTEX        1
20  NO. OF TURBULENT RUNS                       5

 TYPE THE ITEM NUMBER (1-20) TO BE CHANGED.
 TYPE  21  IF NO CHANGES ARE TO BE MADE.
```

Figure A-3. Screen 3. Output flags and default values.



```
THE FOLLOWING DATA DESCRIBES THE DROPLET WHICH IS
INJECTED INTO THE FURNACE

1  INITIAL DROPLET DIAMETER  (M)              0.21E-03
2  INITIAL VELOCITY OF DROPLET  (M/S)         7.00
3  X COMPONENT OF VELOCITY                    0.8660
4  Y COMPONENT OF VELOCITY                    -.5000
5  Z COMPONENT OF VELOCITY                    0.0000
6  INITIAL DROPLET SPACING (L/D)                155.00

TYPE THE NUMBER OF THE DATA TO BE CHANGED (1-6) OR TYPE 7
TO SAVE THE CURRENT DATA
```

Figure A-4. Screen 4. Initial droplet properties.

```
C                          DROP2D
C
C     - 2-DIMENSIONAL VERSION OF THE DROPLET TRAJECTORY CODE
C     - THIS CODE WILL PREDICT THE HEATING, MOTION AND EVAPORATION OF A
C       SINGLE DROPLET INJECTED INTO A HEATED ENVIRONMENT.
C     - THE MODEL IS BASED ON THE ORIGINAL WORK OF AYERS AND SWITHENBANK.
C       FOR MORE INFORMATION ABOUT THE MODEL OR THE INPUT VARIABLES,
C       REFER TO THE USER'S MANUAL.
C
C     MODIFIED BY MARK S. SHELDON FROM ORIGINAL CODE BY WYMAN CLARK
C                 ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION
C                 18 MASON
C                 IRVINE, CALIFORNIA  92718
C                 (714) 859-8851
C     CURRENT VERSION DATED 7/85.
C
C     REMODIFIED BY SUSAN B. ROBINSON
C                 ENERGY AND ENVIRONMENTAL RESEARCH CORPORATION
C                 200 EASTOWNE DR., SUITE 203
C                 CHAPEL HILL, NC  27514
C                 (919) 489-1726
C     CURRENT VERSION DATED  5/87.
C
C     PROGRAM DROPCIN
C
C     DROPCIN IS THE MAIN PROGRAM FOR THE 2-DIMENSIONAL
C     HAZARDOUS WASTE INCINERATION MODEL.
C     HERE IT HAS BE MODIFIED TO ACT AS AN INPUT ROUTINE FOR THE
C     DROPLET EVAPORATION MODEL.
C
      REAL MDOTIN
      LOGICAL*1 CASE(80), INCASE, LABEL(70,10)
      INTEGER RMAXP, XMAXP, RMAX,XMAX
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/GASCB/
     1       CPGAS(XMAX,RMAX), DVISCG(XMAX,RMAX), TCONDG(XMAX,RMAX)
     2      ,FO2, FN2, FCO2, FH2O
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)   , YBDY(RMAXP)         ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/INPUT/
     1    MDOTIN, SUMASS ,R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      OPEN(UNIT=1,STATUS='OLD',FILE='DROP2D.DAT')
C       INPUT TEST CONDITIONS:
C                                  CASE NAME,CASE
C                                  NUMBER OF AXIAL,RADIAL ZONES,IX,IY
C
```

```
C                                     ZONE RADII,R
C                                     ZONE LENGTH,XL
C                                     INPUT MASS FLOW,MDOTIN (KG/SEC)
C                                     MASS FRACTION (WET, ASH) CO2,H2O,N2,O2
C                                     ZONE GAS TEMPERATURES,TEMP
C                                     AXIAL AND RADIAL INJECTION INDICES, II,JI
C                                     NUMBER OF RANDOM RUNS TO OBTAIN STATISTICALLY
C                                       AVERAGED OUTPUT
C
      READ(1,5)CASE
 5    FORMAT(80A1)
      READ(1,7)IX,IY
 7    FORMAT(3X,2(I4,5X))
      READ(1,10)(XL(J),J=1,IX)
      READ(1,10)(R(J),J=1,IY)
 10   FORMAT(5(15X,5(1X,F8.4):/))
      READ(1,12)MDOTIN
 12   FORMAT(8X,F8.5)
      READ(1,15)FCO2,FH2O,FN2,FO2
 15   FORMAT(4(6X,F8.5))
      SUMASS=(FCO2/.044)+(FH2O/.018)+(FN2/.028)+(FO2/.032)
      IXPLUS=IX+1
      READ(1,5)(LABEL(I,1),I=1,70)
      DO 30 I=1,IXPLUS
      READ(1,20)(UBDY1(I,J),J=1,IY)
 20   FORMAT(8F8.4)
 30   CONTINUE
      IYPLUS=IY+1
      READ(1,5)(LABEL(I,2),I=1,70)
      DO 60 I=1,IX
      READ(1,20)(VBDY1(I,J),J=1,IYPLUS)
 60   CONTINUE
C
      READ(1,5)(LABEL(I,3),I=1,70)
      DO 80 I=1,IX
      READ(1,70)(TEMP(I,J),J=1,IY)
 70   FORMAT(8F8.2)
 80   CONTINUE
C
      CALL INJECT
      CLOSE(UNIT=1)
C
      STOP
      END
C ---------------------------------------------------------------------------
      SUBROUTINE INJECT
C
C     Written by Mark Sheldon for EER, 4/17/85
C
C     PURPOSE:
C       INJECT is the main subroutine for the hazardous waste
C       injection model.  It returns the distribution of gas-phase
C       waste as it is injected into the combustor.  The overall
C       injection model is a statistical approach based on the droplet
C       trajectory/heating/evaporation model of Ayers,et.al.(1980)
```

```
C
C     SUBROUTINES CALLED BY INJECT      (SOME INDIRECTLY):
C       SETINJ   Calculates data (except gas prop) for other routines
C       GPROP    Calculates gas properties ( Cp, Visc, Therm. Cond.)
C       DROP     Sends droplet through incinerator, zone by zone
C       SPRAY    Gives initial conditions to each droplet
C       DRPMOV   Trajectory/heating/evaporation of drop in 1 timestep
C       SETPRT   Output header from SETINJ
C       GASPRT   Output header from GPROP
C       DRPPRT   Output header from DROP and/or SPRAY
C       INJPRT   Output header from INJECT (final results)
C
        REAL         MDOTIN, LHELIQ
        INTEGER      TIMAX, DSTMAX, DSTRIB
        LOGICAL*1    COMPND(40,20), CASE(80), INCASE
        LOGICAL      BOIL, CNVRG, GETOUT
        INTEGER      RMAXP, XMAXP, ONE, TWO, RMAX, XMAX
C
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26,ONE=10,TWO=50)
C
      COMMON/LIQCB/
     1       TBOIL, TLIQ, RHOLIQ, LHELIQ, CPLIQ, HCOMLQ, AFMRAT
C
      COMMON/DROPCB/
     1       XPOLD, YPOLD, UPOLD, VPOLD, DRPVEL, DINIT, LOD, IT
     2      ,XPINIT, YPINIT, UPINIT, VPINIT, SPACIN, SPACE, VINIT1
C
      COMMON/PARMCB/
     1       NSTEP, DSAFE, TSAFE, ESAFE, TOL1
     2      ,MAXSTP, NRAMP, NDROP, TIMAX
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
      COMMON/PRINT/
     1     DSTRIB(ONE,TWO),DSTMAX,NXMAX,NYMAX,XMEAN,YMEAN,XFINAL,YFINAL
     2     ,XMX,YMAX,XMIN,YMIN,STDVX,STDVY,NXGRID,NYGRID
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)  , YBDY(RMAXP)       ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
C     OUTPUT FILE
C
      OPEN(UNIT=2,FILE='DROP2D.OUT')
C
C     SET INCINERATOR CONDITIONS
C
      CALL SETINJ
      CALL GPROP
C
C     INITIAL LIQUID TEMPERATURE (ASSUMED SAME FOR ALL DROPS)
C
```

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```
      TINIT = TLIQ
C
C     INJECT DROPS AND TALLY THE ENDPOINT DISTRIBUTION
C
      IF(INJOUT(3).EQ.1) INJFL3 = 1
      DO 3000 M = 1,NDROP
      XSUM = 0
      YSUM = 0
      XSQSUM = 0
      YSQSUM = 0
      DO 10 I=1,20
      DO 10 J=1,20
      DSTRIB(I,J) = 0
      IF (INJFL3.EQ.1) INJOUT(3) = 1
 10   CONTINUE
C
      IF(INPTYP(6).EQ.1) GO TO 1100
      DO 1000 IT = 1,TIMAX
        IF(IT.GT.NPRT3) INJOUT(3)=0
        TLIQ = TINIT
        XPOLD = XPINIT
        YPOLD = YPINIT
        UPOLD = UPINIT
        VPOLD = VPINIT
        DO 540 I = 1,IXPLUS
        DO 530 J = 1,IYPLUS
        VMAG = SQRT(UBDY1(I,J)**2 + VBDY1(I,J)**2)
        IF( VMAG.LE.7.62)  SIGMAX = 1.524
        IF( VMAG.LE.7.62)  SIGMAY = 3.048
        IF(VMAG.GT.15.24) SIGMAX = 0.6096
        IF(VMAG.GT.15.24) SIGMAY = 0.9144
        IF(VMAG.GT.7.62.AND.VMAG.LE.15.24) SIGMAX = 1.524
        IF(VMAG.GT.7.62.AND.VMAG.LE.15.24) SIGMAY = 3.048
        CALL RANDOM(STDDEV,N)
        UBDY(I,J) = UBDY1(I.J)+ STDDEV * SIGMAX * N
        CALL RANDOM (STDDEV,N)
        VBDY(I,J) = VBDY1(I,J) + STDDEV * SIGMAY * N
 530  CONTINUE
 540  CONTINUE
C
        CALL DROP
C
      XSUM = XSUM + XPOLD
      YSUM = YSUM + YPOLD
      XSQSUM = XSQSUM + XPOLD **2
      YSQSUM = YSQSUM + YPOLD **2
      IF (XPOLD.GT.XMX) XMX = XPOLD
      IF (YPOLD.GT.YMAX) YMAX = YPOLD
      IF (XPOLD.LT.XMIN) XMIN = XPOLD
      IF (YPOLD.LT.YMIN) YMIN = YPOLD
      IF (IT.LT.TIMAX) GO TO 200
C
C     STATISTICAL CALCULATIONS
C
        XMEAN = XSUM/TIMAX
        YMEAN = YSUM/TIMAX
        STDVX = SQRT(ABS((XSQSUM * TIMAX - XSUM**2)/TIMAX/(TIMAX-1)))
        STDVY = SQRT(ABS((YSQSUM * TIMAX - YSUM**2)/TIMAX/(TIMAX-1)))
C
200   IF(IT.GT.2) GO TO 101
       XFINAL = XPOLD
       YFINAL = YPOLD
       XMIN = XPOLD
       YMIN = YPOLD
       INTX = INT(XPOLD * 100.)
       INTY = INT(YPOLD * 100)
       NXGRID = 10
       NYGRID = 6
        IF(INTX.LT.15) NXGRID = INTX
        IF(INTY.LT.5) NYGRID = INTY
C
 101  IF(XPOLD.GE.XFINAL) GO TO 103
        IADDX = INT(INTX - XPOLD * 100) + 1
        NX = NXGRID - IADDX
        IF (NX.GE.1) GO TO 102
         NXA = IABS(NX) + 1
         NXMAXP = NXMAX + NXA
         NXAP = NXA + 1
         NDIF = NXMAXP - NXAP
         DO 1 JI = 1,NDIF
          I = NXMAXP - JI
          IDUM = I - NXA
          DO 1 J = 1,NYMAX
          DSTRIB(I,J) = DSTRIB(IDUM,J)
          DSTRIB(IDUM,J) = 0
    1    CONTINUE
          NX = 1
          NXMAX = NXMAXP
          NYGRID = NYGRID + NXA
      GO TO 102
 103    IADDX = INT(XPOLD*100 - INTX)
        NX = NXGRID + IADDX
        IF (NX.GT.NXMAX) NXMAX = NX
C
C     TALLY LOCATION OF Y COORDINATE IN FINAL GRID
C
 102  IF(YPOLD.GE.YFINAL) GO TO 105
        IADDY = INT(INTY - YPOLD * 100) + 1
        NY = NYGRID - IADDY
        IF(NY.GE.1) GO TO 104
C
C       SHIFT ENTIRE GRID AND PREVIOUSLY COUNTED POINTS
C
         NYA = IABS(NY) + 1
         NYMAXP = NYMAX + NYA
         NYAP = NYA + 1
         NDIF = NYMAXP - NYAP
         DO 2 JI=1,NDIF
         J = NYMAXP - JI
         IDUM = J - NYA
```

```
          DO 2 I = 1,NXMAX
          DSTRIB(I,J) = DSTRIB(I,IDUM)
          DSTRIB(I,IDUM) = 0
 2        CONTINUE
          NY = 1
          NYMAX = NYMAXP
          NYGRID = NYGRID + NYA
        GO TO 104
 105     IADDY = INT(YPOLD * 100 - INTY)
         NY = NYGRID + IADDY
         IF (NY.GT.NYMAX) NYMAX = NY
C
 104   DSTRIB(NX,NY) = DSTRIB(NX,NY) + 1
       IF (DSTRIB(NX,NY).GT.DSTMAX) DSTMAX = DSTRIB(NX,NY)
 1000  CONTINUE
       GO TO 2000
C
C      CASE WITH NO TURBULENCE
C
1100  TLIQ = TINIT
        IT =1
        XPOLD = XPINIT
        YPOLD = YPINIT
        UPOLD = UPINIT
        VPOLD = VPINIT
      DO 1110 I = 1,IXPLUS
      DO 1120 J = 1,IYPLUS
      UBDY(I,J) = UBDY1(I,J)
      VBDY(I,J) = VBDY1(I,J)
1120  CONTINUE
1110  CONTINUE
      INJOUT(4) = 0
      CALL DROP
C
2000  CONTINUE
C
C     OUTPUT RESULTS OF INJECTION MODEL
C
      OPEN(UNIT=7,FILE='STAT.OUT')
      IF(INJOUT(4).EQ.1) CALL INJPRT
C
3000  CONTINUE
      CLOSE(UNIT=2)
      CLOSE(UNIT=7)
      RETURN
      END
C ----------------------------------------------------------------------
      SUBROUTINE RANDOM(STDDEV,N)
      INTEGER IA(55),START1,START2
      REAL X(500)
C
C    THIS SUBROUTINE GENERATES RANDOM NUMBERS BETWEEN 0 AND 1000
C    AND THEN INSTITUTES A GAUSSIAN DISTRIBUTION FROM THE RANDOM OUTPUT.
C    THE PRIMARY REFERENCE IS FOR THE RANDOM NUMBER GENERATOR IS:
C
```

```
C              R. Rouse and T. Bugnitz
C              Programming the IBM Personal Computer: Fortran 77
C              Holt, Rhinehart, and Winston , 1983
C
      INTEGER    RMAX, XMAX, RMAXP, XMAXP
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
      COMMON/INPUT/
     1      MDOTIN, SUMASS, R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
C      D IS RANDOM NUMBER BETWEEN 0 AND 1000
C
      CALL GETTIM (I1,I2,I3,I4)
      START1 = ( I1 + I2 + I3 + I4 ) * 1000
      CALL IN55(IA,START1)
      JRAND = JRAND + 1
      IF (JRAND.GT.55) JRAND = IRN55(IA)
      D = FLOAT (IA(JRAND)) * 1.0E-9 * 1000
      N = -1
      IF (D.GT.500) N = 1
      IF (D.GT.500) D = D - 500.
C
      IF(D.LT.20.9) STDDEV=0
      IF(D.GE.20.9.AND.D.LT.60.6) STDDEV = 0.1
      IF(D.GE.60.6.AND.D.LT.99.7) STDDEV = 0.2
      IF(D.GE.99.7.AND.D.LT.137.8) STDDEV = 0.3
      IF(D.GE.137.8.AND.D.LT.174.7) STDDEV = 0.4
      IF(D.GE.174.7.AND.D.LT.209.9) STDDEV = 0.5
      IF(D.GE.209.9.AND.D.LT.243.2) STDDEV = 0.6
      IF(D.GE.243.2.AND.D.LT.274.4) STDDEV = 0.7
      IF(D.GE.274.4.AND.D.LT.303.4) STDDEV = 0.8
      IF(D.GE.303.4.AND.D.LT.330.0) STDDEV = 0.9
      IF(D.GE.330.0.AND.D.LT.354.2) STDDEV = 1.0
      IF(D.GE.354.2.AND.D.LT.376.0) STDDEV = 1.1
      IF(D.GE.376.0.AND.D.LT.395.4) STDDEV = 1.2
      IF(D.GE.395.4.AND.D.LT.412.6) STDDEV = 1.3
      IF(D.GE.412.6.AND.D.LT.427.5) STDDEV = 1.4
      IF(D.GE.427.5.AND.D.LT.440.5) STDDEV = 1.5
      IF(D.GE.440.5.AND.D.LT.451.6) STDDEV = 1.6
      IF(D.GE.451.6.AND.D.LT.461.0) STDDEV = 1.7
      IF(D.GE.461.0.AND.D.LT.468.9) STDDEV = 1.8
      IF(D.GE.468.9.AND.D.LT.475.4) STDDEV = 1.9
      IF(D.GE.475.4.AND.D.LT.480.8) STDDEV = 2.0
      IF(D.GE.480.8.AND.D.LT.485.2) STDDEV = 2.1
      IF(D.GE.485.2.AND.D.LT.488.4) STDDEV = 2.2
      IF(D.GE.488.4.AND.D.LT.491.6) STDDEV = 2.3
      IF(D.GE.491.6.AND.D.LT.494.0) STDDEV = 2.4
      IF(D.GE.494.0.AND.D.LT.495.8) STDDEV = 2.5
      IF(D.GE.495.8.AND.D.LT.497.2) STDDEV = 2.6
      IF(D.GE.497.2.AND.D.LT.498.2) STDDEV = 2.7
      IF(D.GE.498.2.AND.D.LT.499.0) STDDEV = 2.8
      IF(D.GE.499.0.AND.D.LT.499.6) STDDEV = 2.9
      IF(D.GE.499.6.AND.D.LT.500.0) STDDEV = 3.0
 10   CONTINUE
      RETURN
      END
```

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```
C
C  ----------------------------------------------
C
C       PROGRAM TO INITIALIZE IA
C
      SUBROUTINE IN55(IA,IX)
      INTEGER IA(1),IX,I,J,K,II
      IA(55) = IX
      J = IX
      K = I
      DO 1 I = 1,54
       II = MOD(21*I,55)
       IA(II) = K
       K = J - K
       IF (K.LT.0) K = K + 1000000000
       J = IA(II)
    1  CONTINUE
C
       I = IRN55(IA)
       I = IRN55(IA)
       I = IRN55(IA)
       RETURN
        END
C
C          FUNCTION SUBPROGRAM TO GENERATE RANDOM NUMBERS
C
      FUNCTION IRN55(IA)
      INTEGER IA(1),I,J
      DO 1 I = 1,24
        J = IA(I) - IA(I + 31)
        IF(J.LT.0) J = J + 1000000000
        IA(I) = J
    1 CONTINUE
C
      DO 2 I = 25,55
        J = IA(I) - IA(I - 24)
        IF(J.LT.0) J = J + 1000000000
        IA(I) = J
    2 CONTINUE
      IRN55 = 1
      RETURN
      END
C -----------------------------------------------------------------------
C          SUBROUTINE SETINJ
C
C     Written by Mark Sheldon for EER, 4/18/85
C     Modified by Susan Robinson for EER, 1/86
C
C     PURPOSE:
C       SETINJ (SETup for INJection) calculates initial data
C       for injection calculation (except gas properties).
C
      REAL         MDOTIN, LHELIQ, NSTEP
      LOGICAL*1    CASE(80), INCASE
      INTEGER      RMAX,XMAX,RMAXP,XMAXP, TIMAX
```

```
C
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/INPUT/
     1      MDOTIN, SUMASS, R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)   , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/DROPCB/
     1       XPOLD, YPOLD, UPOLD, VPOLD, DRPVEL, DINIT, LOD, IT
     2      ,XPINIT, YPINIT, UPINIT, VPINIT, SPACIN, SPACE, VINIT1
C
      COMMON/LIQCB/
     1       TBOIL, TLIQ, RHOLIQ, LHELIQ, CPLIQ, HCOMLQ, AFMRAT
C
      COMMON/PARMCB/
     1       NSTEP, DSAFE, TSAFE, ESAFE, TOL1
     2      ,MAXSTP, NRAMP, NDROP, TIMAX
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
C       DENSITY (KG M**-3), IDEAL GAS AT 1 ATM.
C       (SUMASS IS GMOLES OF GAS PER KG OF GAS)
C
      DENS(SUMASS,TEMPER) = 273./(SUMASS*0.0224*TEMPER)
C
C       INITIALIZE CONSTANT PARAMETERS
C
      PI = 3.14159
C
C       INPUT FROM DATA FILE
C
      READ(1,210)(INCASE(I),I=1,70)
 210  FORMAT(70A1)
C
      READ(1,220)TBOIL,TLIQ
 220  FORMAT(8X,F10.4,9X,F10.4)
C
      READ(1,230)CPLIQ,LHELIQ,HCOMLQ
 230  FORMAT(8X,F10.4,9X,E10.3/8X,E10.3)
C
      READ(1,240)RHOLIQ, XPINIT
 240  FORMAT(8X,F10.4,9X,F10.4)
C
      READ(1,241) YPINIT
 241  FORMAT(8X,F10.4)
C
      READ(1,245) AFMRAT
 245  FORMAT(8X,F10.4)
C
```

```
      READ(1,250)DSAFE
250   FORMAT(8X,F10.4)
C
      READ(1,260)TSAFE,ESAFE
260   FORMAT(8X,F10.4,9X,F10.4)
C
      READ(1,270)TOL1,NRAMP
270   FORMAT(8X,F10.4,9X,I10)
C
      READ(1,280)MAXSTP,NDROP
280   FORMAT(8X,I10,9X,I10)
C
      READ(1,290)NPRT1,NPRT2
      READ(1,290)NPRT3
 290  FORMAT(8X,I10,9X,I10)
C
C         USE OF ARRAY INJOUT
C           INJOUT INTENDED FOR USE AS OUTPUT SWITCH
C           IN SOME CASES USED TO AFFECT CALCULATION WHEN
C           OTHER METHODS ARE TOO PAINFUL OR QUICK WORK
C
C       CURRENTLY (ACTION IF INJOUT=1... OPPOSITE IF INJOUT=0)
C           INJOUT(1) TURNS ON GASPRT
C           INJOUT(2) TURNS ON SETPRT
C           INJOUT(3) TURNS ON DRPPRT
C           INJOUT(4) TURNS ON INJPRT
C           INJOUT(5) TURNS ON GRAVITY IN +X DIRECTION
C           INJOUT(6) TURNS ON GRAVITY IN +Y DIRECTION
C
C         INPTYP, HOWEVER, IS A LOCAL SWITCH FOR SETINJ
C           INPTYP(1) GIVES DUMMY TWALL
C           INPTYP(2) GIVES DUMMY TEMP
C           INPTYP(3) GIVES DUMMY UBDY
C           INPTYP(4) GIVES DUMMY VBDY
C           INPTYP(5) GIVES FLAG FOR APPLYING TURBULENCE
C           INPTYP(6) ALLOWS FOR HEAVY END APPROXIMATION
C
      READ(1,300)INJOUT(1),INJOUT(2)
      READ(1,300)INJOUT(3),INJOUT(4)
      READ(1,300)INJOUT(5),INJOUT(6)
      READ(1,300)INPTYP(1),INPTYP(2)
      READ(1,300)INPTYP(3),INPTYP(4)
      READ(1,300)INPTYP(5),INPTYP(6)
 300  FORMAT(8X,I10,9X,I10)
C
      READ(1,310) TWDUM,TGDUM
      READ(1,310) UDUM,VDUM
310   FORMAT(8X,F10.4,9X,F10.4)
      READ(1,311) TIMAX
311   FORMAT(8X,I10)
C
C        DUMMY INPUT OPTIONS
C
      IF(INPTYP(1).EQ.0)GOTO 410
        DO 420 J=1,IY
        DO 420 I=1,IX
          TWALL(I,J) = TWDUM
420     CONTINUE
410   CONTINUE
C
      IF(INPTYP(2).EQ.0)GOTO 430
        DO 440 J=1,IY
        DO 440 I=1,IX
          TEMP(I,J) = TGDUM
440     CONTINUE
430   CONTINUE
C
      IF(INPTYP(3).EQ.0)GOTO 450
        DO 460 J=1,IY
        DO 460 I=1,IXPLUS
          UBDY1(I,J) = UDUM
460     CONTINUE
450   CONTINUE
C
      IF(INPTYP(4).EQ.0)GOTO 470
        DO 480 J=1,IYPLUS
        DO 480 I=1,IX
          VBDY1(I,J) = VDUM
480     CONTINUE
470   CONTINUE
C
C       COORDINATES OF ZONE BOUNDARIES
C
      XBDY(1) = 0.
      DO 600 I = 1,IX
        XBDY(I+1) = XBDY(I) + XL(I)
600   CONTINUE
C
      YBDY(1) = 0.
      DO 650 J = 1, IY
        YBDY(J+1) = YBDY(J) + R(J)
650   CONTINUE
C
C       AREAS AND VELOCITIES AT ZONE BOUNDARIES
C
      IF(INPTYP(3).EQ.1)GOTO 710
      DO 740 I = 1,IXPLUS
        DO 720 J = 1,IY
          XAREA = PI * (YBDY(J+1)*YBDY(J+1)-YBDY(J)*YBDY(J))
          IF(I.EQ.1) DUM1 = TEMP(I,J)
          IF(I.NE.1.AND.I.NE.IXPLUS)
     1       DUM1 = (TEMP(I,J) + TEMP(I-1,J)) * 0.5
          IF(I.EQ.IXPLUS) DUM1 = TEMP(I-1,J)
          XRHO = DENS(SUMASS,DUM1)
720     CONTINUE
740   CONTINUE
710   CONTINUE
C
      L = 0
      DO 770 I=1,IX
```

```
        IF(VBDY1(I,1).GT.1.E-6)L=1
770   CONTINUE
      IF(L.EQ.1) WRITE(2,780)
780   FORMAT(1X,'***WARNING: FLOW ACROSS CENTERLINE NONZERO'
     1          ,' SEE SETINJ')
C
C       WALL TEMPERATURES (HARDCODED FOR NOW)
C
      IF(INPTYP(1).EQ.1)GOTO 801
        DO 810 J=1,IY
        DO 820 I=1,IX
          TWALL(I,J) = TEMP(I,J)
820     CONTINUE
810   CONTINUE
801   CONTINUE
C
C       OPTIONAL OUTPUT
C
      IF(INJOUT(2).EQ.1) CALL SETPRT
C
      RETURN
      END
C ---------------------------------------------------------------------
      SUBROUTINE GPROP
C
C     Written by Mark Sheldon for EER, 4/16/85
C
C     PURPOSE:
C       GPROP (Gas PROPerties) calculates the heat capacity, viscosity,
C       and thermal conductivity of an ideal gas mixture including:
C
C       No.  Formula        Name
C        1     O2      Diatomic Oxygen
C        2     N2      Diatomic Nitrogen
C        3     CO2     Carbon Dioxide
C        4     H2O     Water Vapor
C
C       Primary Reference:
C          Reid, Prausnitz and Sherwood  (1977)
C          The Properties of Gases and Liquids, 3rd ed.
C
C       LOCAL VARIABLES
C
        REAL*4 CP(4)     , VISC(4)  , COND(4)
     1        ,MASSFR(4) , MOLEFR(4), MOLWT(4)
     2        ,SIGMA(4)  , EPS(4)   , DELTA(4)
     3        ,TCRIT(4)  , KALPH(4) , KCIR(4)
     4        ,VAFUN(4,4), VWGT(4)  , KWGT(4)
     5        ,VFUDGE(4) , CFUDGE(4), KFUDGE(4)
     6        ,DUM1      , DUM2     , DUM3      , DUM4    , DUM5
     7        ,DUM6      , DUM7     , DUM8      , DUM9
     8        ,TDUM1     , TDUM2
       INTEGER I, J, K, L, M, NGSPEC, IPOLAR(4)
C
C       COMMON VARIABLES FROM MAIN PROGRAM
```

```
C
      REAL MDOTIN
      INTEGER RMAX,XMAX,RMAXP,XMAXP
      LOGICAL*1 CASE(80), INCASE
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/INPUT/
     1      MDOTIN, SUMASS ,R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)  , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/GASCB/
     1       CPGAS(XMAX,RMAX), DVISCG(XMAX,RMAX), TCONDG(XMAX,RMAX)
     2      ,FO2, FN2, FCO2, FH2O
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
C        MOLECULAR PARAMETERS
C
C        NUMBER OF GAS SPECIES
      DATA NGSPEC/4/
C
C        MOLECULAR WEIGHTS (G/GMOLE)
      DATA MOLWT /32.00    , 28.02    , 44.01    , 18.02    /
C
C        LENNARD-JONES (AND STOCKMEYER) PARAMETERS
C        (SIGMA IN ANGSTROMS, EPS IN KELVIN)
      DATA SIGMA /3.433    , 3.681    , 3.996    , 2.52     /
      DATA EPS   /113.     , 91.5     , 190.     , 775.     /
      DATA DELTA /0.0      , 0.0      , 0.0      , 1.0      /
C
C        CRITICAL TEMPERATURES (KELVIN)
      DATA TCRIT /154.8    , 126.2    , 304.2    , 647.3    /
C
C        PARAMETERS FOR POLAR VERSION OF THERMAL CONDUCTIVITY
C        (IPOLAR IS FLAG: =0 IF NONPOLAR, =1 IF POLAR)
C        (ALPHA AND CIR HAVE UNITS OF CAL/GMOLE/KELVIN)
      DATA IPOLAR/       0,         0,         0,         1/
      DATA KALPH / 0.0     , 0.0      , 0.0      , 0.90     /
      DATA KCIR  / 0.0     , 0.0      , 0.0      , 0.0      /
C
C        FUDGE FACTORS ARE RATIOS OF EXPERIMENTAL TO CALCULATED VALUES
C        AT REFERENCE TEMPERATURE (1300 K UNLESS OTHERWISE NOTED)
C
C        NOTE: BEGIN BY USING FUDGE FACTORS SET TO 1.0
C
      DATA VFUDGE/ 1.0     , 1.0      , 1.0      , 1.0      /
      DATA KFUDGE/ 1.0     , 1.0      , 1.0      , 1.0      /
      DATA CFUDGE/ 1.0     , 1.0      , 1.0      , 1.0      /
C
```

```
C       TEMPERATURE-INDEPENDENT CALCULATIONS
C
C       MASS FRACTIONS
C
      MASSFR(1) = FO2
      MASSFR(2) = FN2
      MASSFR(3) = FCO2
      MASSFR(4) = FH2O
C
C       CHECK MASSFR NORMALIZATION
C
      DUM1 = -1.
      DO 210 L = 1,NGSPEC
        DUM1 = MASSFR(L) + DUM1
210    CONTINUE
      IF(DUM1.LT.-1.E-6) WRITE(2,220) DUM1
220   FORMAT(1X,'***WARNING: SUM OF MASS FRACTIONS IS '
     1          ,E10.3,' BELOW 1')
      IF(DUM1.GT.+1.E-6) WRITE(2,230) DUM1
230   FORMAT(1X,'***WARNING: SUM OF MASS FRACTIONS IS '
     1          ,E10.3,' ABOVE 1')
C
C       MOLE FRACTIONS
C
      DUM1 = 0.
      DO 310 L = 1, NGSPEC
        DUM1 = DUM1 + MASSFR(L)/MOLWT(L)
310   CONTINUE
      DO 320 L = 1, NGSPEC
      MOLEFR(L) = (MASSFR(L)/MOLWT(L) ) / DUM1
320   CONTINUE
C
C       TEMPERATURE INDEPENDENT WEIGHTING FUNCTION (A) FOR MIX VISCOSITY
C
      DO 330 M = 1, NGSPEC
      DO 330 L = 1, NGSPEC
        DUM1 = MOLWT(L) / MOLWT(M)
        DUM2 = ( 4./ (1. + 1./DUM1) / (1. + DUM1) )**0.25
        DUM3 = DUM2 * (DUM1**(-0.5))
        DUM4 = DUM1 - (DUM1**(0.45))
        DUM5 = 2. * (1. + DUM1)
        DUM6 = (1. + (DUM1**(0.45)) ) * (DUM2**(-0.5))
        DUM7 = 1. + DUM2
        VAFUN(L,M) = DUM3 * (1. + DUM4/ (DUM5 + DUM6/DUM7) )
330   CONTINUE
C
C       LOOP THROUGH ALL ZONES I,J
C
      DO 1000 J = 1, IY
      DO 1000 I = 1, IX
C
C       LOOP FOR PURE COMPONENT PROPERTIES
C
      DO 2000 L = 1, NGSPEC
C
```

```
C        PURE COMPONENT HEAT CAPACITY
C
      TDUM1 = TEMP(I,J)*1.8
C
      IF(TDUM1.LT.540.) WRITE(2,410) TDUM1
410   FORMAT(1X,'***WARNING: GAS TEMP=',F8.1,/,1X
     1         ,'FARENHEIT, TOO LOW  FOR EMPIRICAL CP EQNS. IN GPROP')
      IF(TDUM1.GT.5000.)WRITE(2,420) TDUM1
420   FORMAT(1X,'***WARNING: GAS TEMP=',F8.1,/,1X
     2         ,'FARENHEIT, TOO HIGH FOR EMPIRICAL CP EQNS. IN GPROP')
C
      IF(L.EQ.1) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * ( 11.515 - 172.*( TDUM1**(-0.5) ) + 1530./TDUM1 )
C
      IF(L.EQ.2) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * (  9.47  - 3.47E3 / TDUM1          + 1.16E6/TDUM1/TDUM1 )
C
      IF(L.EQ.3) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * ( 16.2   - 6.53E3 / TDUM1          + 1.41E6/TDUM1/TDUM1 )
C
      IF(L.EQ.4) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * ( 19.86  - 597.*( TDUM1**(-0.5) ) + 7500./TDUM1 )
C
C        PURE COMPONENT VISCOSITY
C        (DUM1 IS THE INTEGRAL 'OMEGA' BASED ON STOCKMEYER POTENTIAl)
C
      TDUM1 = TEMP(I,J)/EPS(L)
C
      IF(TDUM1.LT.0.3) WRITE(2,430) TDUM1, L, I, J
430   FORMAT(1X,'WARNING: NONDIMEN TEMP = ',F6.2
     1         ,' FOR SPECIES L=',I3,'T ZONE I=',I3,', J=',I3,/
     2       1X,9X,'TOO LOW FOR ACCURATE VISCOSITY PREDICTION')
C
      IF(TDUM1.GT.100.) WRITE(2,440) TDUM1, L, I, J
440   FORMAT(1X,'WARNING: NONDIMEN TEMP = ',F6.2
     1         ,' FOR SPECIES L=',I3,' AT ZONE I=',I3,', J=',I3,/
     2       1X,9X,'TOO HIGH FOR ACCURATE VISCOSITY PREDICTION')
C
      DUM1  =  1.16145 / (TDUM1**0.14874)
     1       + 0.52487 * EXP(-0.77320*TDUM1)
     2       + 2.16178 * EXP(-2.43787*TDUM1)
     3       + 0.2 * DELTA(L) * DELTA(L) / TDUM1
C
      VISC(L) = (26.69E-7 * SQRT( MOLWT(L)*TEMP(I,J) )
     1         / SIGMA(L) / SIGMA(L) / DUM1)
     2         * VFUDGE(L)
C
C        PURE COMPONENT THERMAL CONDUCTIVITY
C        (EQUATION HAS 2 FORMS, FOR NONPOLAR AND POLAR SPECIES)
C
      TDUM2 = TEMP(I,J)/TCRIT(L)
C
      IF(IPOLAR(L).EQ.0) COND(L) = (4.184E3 * VISC(L) / MOLWT(L))
     1     * (  3.107E-4 * CP(L) * MOLWT(L)
     2        - (0.70 / TDUM2) + 0.9168 )
     3     * KFUDGE(L)
C
      IF(IPOLAR(L).EQ.1) COND(L) = (4.184E3 * VISC(L) / MOLWT(L))
     1     * (  3.107E-4 * CP(L) * MOLWT(L)
     2         - (0.69 / TDUM2) + 1.077
     3         - (3. * KALPH(L)) - (0.3 * KCIR(L))  )
     4     * KFUDGE(L)
C
 2000 CONTINUE
C
C       LOOP FOR MIXTURE WEIGHTING FUNCTIONS
C
      DO 3000 L = 1, NGSPEC
      VWGT(L) = 0.
      KWGT(L) = 0.
      DO 3000 M = 1, NGSPEC
C
C       VISCOSITY WEIGHTING FUNCTION
C
      DUM2 = 1.0
      IF((DELTA(L).GE.0.1).OR.(DELTA(M).GE.0.1))
     1 DUM2 = ( 1. + SQRT( (TEMP(I,J)/EPS(L)) * (TEMP(I,J)/EPS(M)) )
     2              + DELTA(L) * DELTA(M) * 0.25 )
     3        /SQRT( 1. + TEMP(I,J)/EPS(L) + DELTA(L)*DELTA(L)*0.25 )
     4        /SQRT( 1. + TEMP(I,J)/EPS(M) + DELTA(M)*DELTA(M)*0.25 )
C
      DUM3 = DUM2 * VAFUN(L,M) * SQRT( VISC(L)/VISC(M) )
C
      VWGT(L) = VWGT(L) + DUM3 * MOLEFR(M)
C
C       THERMAL CONDUCTIVITY WEIGHTING FUNCTION
C
      DUM4 = ( 1. + SQRT( VISC(L)/VISC(M) )
     1             *( MOLWT(M)/MOLWT(L) )**0.25 )**2.
     2       / SQRT( 8. * (1. + MOLWT(L)/MOLWT(M) ) )
C
      KWGT(L) = KWGT(L) + DUM4 * MOLEFR(M)
C
 3000 CONTINUE
C
C       MIXTURE PROPERTIES
C
      CPGAS(I,J)  = 0.0
      DVISCG(I,J) = 0.0
      TCONDG(I,J) = 0.0
C
      DO 4000 L = 1, NGSPEC
        CPGAS(I,J)  = CPGAS(I,J)  + CP(L)   * MASSFR(L)
        DVISCG(I,J) = DVISCG(I,J) + VISC(L) * MOLEFR(L) / VWGT(L)
        TCONDG(I,J) = TCONDG(I,J) + COND(L) * MOLEFR(L) / KWGT(L)
 4000 CONTINUE
C
 1000 CONTINUE
C
C       OPTIONAL OUTPUT
```

```
C
      IF(INJOUT(1).EQ.1) CALL GASPRT
C
      RETURN
      END
C ----------------------------------------------------------------------
      SUBROUTINE DROP
C
C     Written by Mark Sheldon for EER, 4/85
C
C     PURPOSE:
C       Return statistical evaporation zone of single liquid droplet.
C       Axisymetric cylindrical coordinates.
C
      INTEGER   COUNT1, COUNT2, DSTMAX
      LOGICAL   BOIL, CNVRG, GETOUT, FNUF
      REAL      MDOTIN, LHELIQ, NSTEP, NUSELT , LOD
      INTEGER   RMAX,XMAX ,RMAXP,XMAXP, START1, START2, TIMAX
      LOGICAL*1 CASE(80), INCASE
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/MOVECB/
     1        DTIME, DTSAV, OLDDT, TIME
     2       ,DIAM,  UGAS , VGAS , PRANDT
     3       ,IINEW, JINEW, COUNT1, COUNT2
     4       ,BOIL , CNVRG, GETOUT, DT, START1, START2
C
      COMMON/INPUT/
     1      MDOTIN, SUMASS ,R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      COMMON/ZBDYCB/
     1        UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2       ,XBDY(XMAXP)  , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3       ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/GASCB/
     1        CPGAS(XMAX,RMAX), DVISCG(XMAX,RMAX), TCONDG(XMAX,RMAX)
     2       ,FO2, FN2, FCO2, FH2O
C
      COMMON/LIQCB/
     1        TBOIL, TLIQ, RHOLIQ, LHELIQ, CPLIQ, HCOMLQ, AFMRAT
C
      COMMON/DROPCB/
     1        XPOLD, YPOLD, UPOLD, VPOLD, DRPVFL, DINIT, LOD, IT
     2       ,XPINIT, YPINIT, UPINIT, VPINIT, SPACIN, SPACE, VINIT1
C
      COMMON/PARMCB/
     1        NSTEP, DSAFE, TSAFE, ESAFE, TOL1
     2       ,MAXSTP, NRAMP, NDROP, TIMAX
C
      COMMON/PRTCB/
     1        CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
      COMMON/SAVE/
     1        SAVEII,SAVEJI
C
C       DENSITY (KG M**-3), IDEAL GAS AT 1 ATM
C           (SUMASS IS GMOLES PER KG OF GAS MIXTURE)
C
      DENS(SUMASS,TEMPER) = 273./(SUMASS*0.0224*TEMPER)
C
C        DROPLET INITIAL CONDITIONS
C
      IF(IT.EQ.1) CALL SPRAY
      XPOLD = XPINIT
      YPOLD = YPINIT
      UPOLD = UPINIT
      VPOLD = VPINIT
       II = SAVEII
       JI = SAVEJI
C
C        INITIALIZATIONS
C
 30   BOIL   = .FALSE.
      IF(TLIQ.GE.TBOIL) BOIL = .TRUE.
      IF(TLIQ.GT.TBOIL.AND.INJOUT(3).EQ.1) WRITE(2,50)
 50   FORMAT(1X,'SUPERHEATED DROPLET')
      CNVRG  = .FALSE.
      GETOUT = .FALSE.
      ENUF   = .FALSE.
      IINEW  = II
      JINEW  = JI
      DIAM   = DINIT
      TIME   = 0.0
      DT     = 0.0
      DTIME  = 1.0E-4
C
C        INITIALIZE GAS VELOCITY
C
      UGAS = UBDY(II,JI) + (UBDY(II+1,JI) - UBDY(II,JI))
     1                   *(XPOLD - XBDY(II)) / (XBDY(II+1) - XBDY(II))
      VGAS = VBDY(II,JI) + (VBDY(II,JI+1) - VBDY(II,JI))
     1                   *(YPOLD - YBDY(JI)) / (YBDY(JI+1) - YBDY(JI))
C
      VINIT = SQRT( (UPOLD-UGAS)**2 + (VPOLD-VGAS)**2 )
      VINIT1 = SQRT( UPOLD**2 + VPOLD**2)
C
C        ZONE CALCULATIONS
C            (ARBITRARY SAFETY LIMIT SET ON NUMBER OF ZONE PASSES)
C
      DO 1000 COUNT1 = 1,MAXSTP
C
      IF(UPOLD.EQ.UGAS.AND.VPOLD.EQ.VGAS) WRITE(6,101)
      IF(UPOLD.EQ.0.AND.VPOLD.EQ.0) WRITE(6,102)
 101  FORMAT (2X,'DROP VELOCITY EQUALS GAS VELOCITY')
 102  FORMAT (2X,'DROP VELOCITY EQUALS ZERO')
      VMAG = SQRT( (UPOLD-UGAS)**2 + (VPOLD-VGAS)**2 )
      VDT = SQRT(UPOLD**2 + VPOLD **2)
C
```

```
      RENOLD = DIAM * DENS(SUMASS,TEMP(II,JI)) * VMAG / DVISCG(II,JI)
      TRANSNO = CPGAS(II,JI) * (TEMP(II,JI)-TLIQ) /LHELIQ +
     1          HCOMLQ * FO2 / ATMRAT /LHELIQ
C
      IF(RENOLD.LE.80) CDINF = 27. * RENOLD**(-0.84)
      IF(RENOLD.GT.80.AND.RENOLD.LT.1.E4)
     1        CDINF = 0.271 * RENOLD**(0.217)
      IF(RENOLD.GE.1.E4) CDINF = 2.
C
C       ADJUST DRAG COEFFICIENT FOR CLOSELY SPACED DROPLETS
C
      SPACE = VDT * SPACIN / VINIT1
      IF (SPACE.LT.DIAM) SPACE = DIAM
      CD2 = 0.755/RENOLD + 34.8 * RENOLD**(-1.009) * (SPACE/DIAM-1)
      EXP1= -1/.7072
      CD = (CDINF ** (-0.7072) + CD2 ** (-0.7072)) ** EXP1
C
C       ETAE ACCOUNTS FOR EFFECT OF MASS TRANSFER (EVAP) ON DRAG
C
      ETAE = 1.
      IF(BOIL) ETAE  = 1 / ( 1 + TRANSNO )
      CDINF = CDINF * ETAE
      CD    = CD * ETAE
      CDRE  = CD * RENOLD
C
C       CONSTANTS FOR TIMESTEP CALCULATION
C
      CON1 = -1.
      IF(CDRE.GT.1.E-10)
     1        CON1 = 1./( 0.75 * DVISCG(II,JI) / RHOLIQ / DIAM / DIAM
     2        * CDRE )
C
      PRANDT = CPGAS(II,JI) * DVISCG(II,JI) / TCONDG(II,JI)
      NUSELT = 2. + 0.6 * (RENOLD**0.5) * (PRANDT**(1./3.))
      CON2 = RHOLIQ * DIAM * DIAM * CPLIQ / 6. / NUSELT / TCONDG(II,JI)
C
      CBOIL = -1.
      IF(TEMP(II,JI).GE.TLIQ) CBOIL =
     1     8. * TCONDG(II,JI) / RHOLIQ / CPGAS(II,JI)
     2     *ALOG(1. + TRANSNO)
      CON3 = DIAM*DIAM/CBOIL/(1. + 0.23*(RENOLD**0.5))
C
C       TIMESTEP SIZE
C
      OLDDT = DTIME
C
      TIME1 = 1.E20
      IF(UPOLD.GT.+1.E-7) TIME1 = (XBDY(II+1) - XPOLD) /UPOLD / 2
      IF(UPOLD.LT.-1.E-7) TIME1 = (XBDY(II)   - XPOLD) /UPOLD / 2
C
      TIME2 = 1.E20
      IF(VPOLD.GT.+1.E-7) TIME2 = (YBDY(JI+1) - YPOLD) /VPOLD / 2
      IF(VPOLD.LT.-1.E-7) TIME2 = (YBDY(JI)   - YPOLD) /VPOLD / 2
C
      TIME3 = 1.E20
      IF(CON1.GE.0.) TIME3 = CON1*DSAFF
C
      TIME4 = 1.E20
      IF(.NOT.BOIL) TIME4 = CON2*TSAFE
C
      TIME5 = 1.E20
      IF(CBOIL.GE.0.) TIME5 = CON3*ESAFE
C
      DUM1 = DTIME
      IF(TIME2.GE.0.0.AND.TIME2.LE.DUM1) DUM1 = TIME2
      IF(TIME3.GE.0.0.AND.TIME3.LE.DUM1) DUM1 = TIME3
      IF(TIME4.GE.0.0.AND.TIME4.LE.DUM1) DUM1 = TIME4
      IF(TIME5.GE.0.0.AND.TIME5.LE.DUM1) DUM1 = TIME5
      IF(DUM1.LE.1.E+21) DTIME = DUM1
      DTSAV = DTIME
C
C       TIMESTSTEPS ACROSS ZONE
C
      DO 2000 COUNT2 = 1,MAXSTP
        CALL DRPMOV
        IF(GETOUT) GOTO 600
C
C       CHECK FOR ZONE BOUNDARY
C       IF STILL IN ZONE, CONTINUE IN 'DO 2000' LOOP FOR NEXT TIMESTEP
C       IF ZONE BOUNDARY REACHED, GET OUT OF 'DO 2000' LOOP
C
      IF (IINEW.NE.II) GOTO 600
      IF (JINEW.NE.JI) GOTO 600
 2000 CONTINUE
C
C     IF NOT OUT OF ZONE IN REASONABLE TIME, DROPLET MAY BE OUT OF STEAM
C
      IF (INJOUT(3).EQ.1) WRITE(2,620)MAXSTP
 620  FORMAT(1X,/,1X,'STILL IN ZONE AFTER ',I7,' STEPS.')
      RETURN
C
C       END-OF-ZONE CALCULATIONS
C
 600  CONTINUE
C
C       CHECK WHETHER ZONE BOUNDARY IS A SOLID WALL
C
      IF(IINEW.EQ.0) ENUF = .TRUE.
      IF(IINEW.EQ.IXPLUS) ENUF = .TRUE.
      IF(JINEW.EQ.IYPLUS) ENUF = .TRUE.
      IF(.NOT.ENUF) GOTO 700
C
      IF(BOIL.OR.TWALL(II,JI).GT.TBOIL) GO TO 630
      IF(INJOUT(3).EQ.1) WRITE(2,610)
 610  FORMAT(1X,'DROP CONDENSED ON COLD SURFACE, WILL NOT BOIL')
      RETURN
C
 630  CONTINUE
      IF(INJOUT(3).EQ.1) WRITE(2,640)
 640  FORMAT(1X,'ICSDRP: DROP ON WALL, WILL EVAPORATE IN THIS ZONE')
```

```
      RETURN
C
C       CHECK FOR EVAPORATION IN PAST ZONE
C
700   CONTINUE
      DMASS =  (DIAM / DINIT)**3.
      IF(DIAM.LT.1.0E-6) GOTO 710
      DUM1 = DIAM*1.E6
      DUM2 = 1. - DMASS
      IF (INJOUT(3).EQ.1) WRITE(2,720)II,JI,COUNT2,TIME,XPOLD,YPOLD
     1       ,UPOLD,VPOLD,TLIQ,DUM1,DUM2
720   FORMAT(1X,I3,I3,I5,E10.3,F7.4,F7.4,2(F7.3),F7.1,F8.2,F8.3/)
      RETURN
C
C       IF NOT EVAPORATED, ENTER NEW ZONE
C
710   CONTINUE
      II = IINEW
      IF(JINEW.NE.0) GOTO 800
        VPOLD = -VPOLD
        JINEW = 1
800   CONTINUE
      JI = JINEW
C
C       IF TEMP OF NEW ZONE IS < TBOIL, RECALCULATE DROP TEMP
C
      IF(TEMP(II,JI).LT.TBOIL) BOIL = .FALSE.
C
1000  CONTINUE
C
C       IF ZONE LOOP COMPLETED WITHOUT EVAPORATION, SEND WARNING MESSAGE
C
      IF(INJOUT(3).EQ.1) WRITE(2,900) MAXSTP
900   FORMAT(1X,'DROPLET NOT EVAPORATED AFTER ',I8,' ZONES VISITED')
      RETURN
      END
C ---------------------------------------------------------------------
      SUBROUTINE SPRAY
C     Written by Mark Sheldon, 4/18/85
C
C     PURPOSE:
C       SPRAY returns droplet initial conditions to DROP.
C
      REAL      MDOTIN, LOD, LHELIQ , NSTEP
      LOGICAL*1 CASE(80), INCASE
      INTEGER   RMAXP, XMAXP, RMAX, XMAX, TIMAX
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/INPUT/
     2     MDOTIN, SUMASS ,R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)  , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
```

```
C
      COMMON/DROPCB/
     1       XPOLD, YPOLD, UPOLD, VPOLD, DRPVEL, DINIT, LOD, IT
     2      ,XPINIT, YPINIT, UPINIT, VPINIT, SPACIN, SPACE, VINITI
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
      COMMON/SAVE/
     1       SAVEII,SAVEJI
C
C      INPUT FROM DATA FILE
C
      READ(1,100) DINIT
      READ(1,101) DRPVEL,XPCOMP
      READ(1,101) YPCOMP, LOD
100   FORMAT(8X,E10.3)
101   FORMAT(8X,F10.4)
C
C       CHANGE L/D TO SPACING
C
      SPACIN = LOD * DINIT
C
C     DROPLET INITIAL VELOCITY
C
      UPOLD = DRPVEL * XPCOMP
      VPOLD = DRPVEL * YPCOMP
      UPINIT= UPOLD
      VPINIT= VPOLD
C
C       LOCATE INITIAL ZONE
C
      II = 1
      DO 200 I = 2, IXPLUS
        IF(XPOLD.LT.XBDY(I)) GOTO 210
        II = II + 1
200   CONTINUE
210   CONTINUE
      IF(II.GT.IX) II = IX
C
      JI = 1
      DO 300 J = 2, IYPLUS
        IF(YPOLD.LT.YBDY(J)) GOTO 310
        JI = JI + 1
300   CONTINUE
310   CONTINUE
      IF(JI.GT.IY) JI = IY
      SAVEII=II
      SAVEJI=JI
C
       IF(INJOUT(3).EQ.1) CALL DRPPRT
C
      RETURN
      END
```

```
C ---------------------------------------------------------------------
      SUBROUTINE DRPMOV
C
C     Written by Mark Sheldon for EER, 4/85
C     Revised by Susan Robinson for EER 9/86
C
C     PURPOSE:
C       DRPMOV (DRoPlet MOVe) calculates the motion, heating, and
C       evaporation of a single droplet during a single timestep.
C
      LOGICAL PRTLIN,WZCOLD, BOIL, CNVRG, GETOUT
      INTEGER  COUNT1, COUNT2,RMAXP,XMAXP, RMAX, XMAX
      REAL MDOTIN,LHELIQ,  NSTEP, NUSELT, N, LOD
      LOGICAL*1 CASE(80), INCASE
      INTEGER  START1, START2
C
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/MOVECB/
     1       DTIME , DTSAV , OLDDT , TIME
     2      ,DIAM  , UGAS  , VGAS  , PRANDT
     3      ,IINEW , JINEW , COUNT1, COUNT2
     4      ,BOIL  , CNVRG,  GETOUT, DT, START1, START2
C
      COMMON/INPUT/
     1      MDOTIN, SUMASS ,R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)   , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/GASCB/
     1       CPGAS(XMAX,RMAX), DVISCG(XMAX,RMAX), TCONDG(XMAX,RMAX)
     2      ,FO2, FN2, FCO2, FH2O
C
      COMMON/LIQCB/
     1       TBOIL, TLIQ, RHOLIQ, LHELIQ, CPLIQ, HCOMLQ, AFMRAT
C
      COMMON/DROPCB/
     1       XPOLD, YPOLD, UPOLD, VPOLD, DRPVEL, DINIT, LOD, IT
     2      ,XPINIT, YPINIT, UPINIT, VPINIT, SPACIN, SPACE, VINITI
C
      COMMON/PARMCB/
     1       NSTEP, DSAFE, TSAFE, ESAFE, TOL1
     2      ,MAXSTP, NRAMP, NDROP, TIMAX
C
         COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
C        DENSITY (KG M**-3), IDEAL GAS AT 1 ATM
C          (SUMASS IS GMOLES PER KG OF GAS MIXTURE)
C
       DENS(SUMASS,TEMPER) = 273./(SUMASS*0.0224*TEMPER)
```

```
C
C        TRANSFER NUMBER (FOR EQUATION OF dD/dt AND ETAE)
C
      TRANSNO = CPGAS(II,JI) * (TEMP(II,JI)-TLIQ) /LHELIQ +
     1          HCOMLQ * FO2 / AFMRAT /LHELIQ
C
C       OUTPUT LOGIC
C
      PRTLIN = .FALSE.
      IF(COUNT2.LE.NPRT1) PRTLIN = .TRUE.
      IF(MOD(COUNT2,NPRT2).EQ.0) PRTLIN = .TRUE.
      WZCOLD = .FALSE.
      STEPM = 0.100
      DUM1 = 1.0 - (DIAM/DINIT)**3
      MGOAL1 = INT(DUM1/STEPM)
C
C       ADJUST TIMESTEP FOR EARLY PART OF ZONE
C
      DTIME = DTSAV
      IF(COUNT2.LE.NRAMP.AND.COUNT1.EQ.1)
     1     DTIME = DTSAV*FLOAT(COUNT2)/FLOAT(NRAMP)
C
C       ADJUST TIMESTEP FOR EVAPORATING DROPLET
C
        DTIME = DTIME * (DIAM/DINIT)**2
C
C       UPDATE DROP POSITION
C
      XPNEW = XPOLD + UPOLD*DTIME
      DUM1 = XBDY(II+1) + 1.0E-8
      IF(XPNEW.LT.DUM1) GOTO 300
        IINEW = II + 1
        DTIME = (XBDY(II+1) - XPOLD) /UPOLD
        XPNEW = XBDY(II+1)
  300 CONTINUE
      DUM2 = XBDY(II) - 1.0E-8
      IF(XPNEW.GT.DUM2) GOTO 310
        IINEW = II - 1
        DTIME = (XBDY(II) - XPOLD) /UPOLD
        XPNEW = XBDY(II)
  310 CONTINUE
C
      YPNEW = YPOLD + VPOLD*DTIME
      DUM3 = YBDY(JI+1) + 1.0E-8
      IF(YPNEW.LT.DUM3) GOTO 320
        JINEW = JI + 1
        DTIME = (YBDY(JI+1) - YPOLD) /VPOLD
        YPNEW = YBDY(JI+1)
  320 CONTINUE
      DUM4 = YBDY(JI) - 1.0E-8
      IF(YPNEW.GT.DUM4) GOTO 330
        JINEW = JI - 1
        DTIME = (YBDY(JI) - YPOLD) /VPOLD
        YPNEW = YBDY(JI)
  330 CONTINUE
```

```
C
C       CHECK FOR NEGATIVE OR HUGE TIMESTEPS NEAR BOUNDARY
C        (NEGATIVE TIMESTEP MEANS XPOLD WAS ACTUALLY IN NEW ZONE)
C        (HUGE TIMESTEP MEANS DROPLET VELOCITY VERY SMALL)
C
      IF(II.EQ.IINEW.AND.JI.EQ.JINEW) GO TO 340
        DUM1 = DTIME
        IF(DUM1.GE.0.0) GOTO 341
          DTIME = OLDDT
          GETOUT = .TRUE.
          RETURN
341     CONTINUE
        IF(DUM1.GE.1.E22) DTIME = OLDDT
340   CONTINUE
C
C       UPDATE DROPLET VELOCITY AT NEW POSITION
C       (CDRE IS DRAG COEFF X REYNOLD NUMBER)
C
      VRELX   = UPOLD - UGAS
      VRELY   = VPOLD - VGAS
      VRELMAG = SQRT( VRELX**2 + VRELY**2 )
      VDMAG   = SQRT( UPOLD**2 + VPOLD**2 )
C
C       ALLOWANCE FOR GRAVITY IN THE +X OR +Y DIRECTION
C
      GRAVX = 0.0
      GRAVY = 0.0
      IF(INJOUT(5).EQ.1) GRAVX = 9.81
      IF(INJOUT(6).EQ.1) GRAVY = 9.81
C
      RENOLD = DIAM * DENS(SUMASS,TEMP(II,JI)) * VRELMAG / DVISCG(II,JI)
C
      IF(RENOLD.LE.80) CDINF = 27. * RENOLD**(-0.84)
      IF(RENOLD.GT.80.AND.RENOLD.LT.1.E4)
     1         CDINF = 0.271 * RENOLD**(0.217)
      IF(RENOLD.GE.1.E4) CDINF = 2.
C
C       ADJUST DRAG COEFFICIENT FOR CLOSELY SPACED DROPLETS
C
      SPACE = VDMAG * SPACIN / VINIT1
      IF (SPACE.LT.DIAM) SPACE = DIAM
      CD2 = 0.755/RENOLD + 34.8 * RENOLD**(-1.009) * (SPACE/DIAM-1)
      EXP1 = -1/0.7072
      CD = (CDINF ** (-0.7072) + CD2 **(-0.7072)) **EXP1
C
C       ETAE ACCOUNTS FOR EFFECT OF MASS TRANSFER (EVAP) ON DRAG
C
      ETAE = 1.
      IF(BOIL) ETAE  = 1 / ( 1 + TRANSNO )
      CDINF = CDINF * ETAE
      CD    = CD * ETAE
C
C
      VR1MAG = VRELX * UPOLD/VDMAG + VRELY * VPOLD/VDMAG
      VR1X = VR1MAG * UPOLD/VDMAG
```

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```
      VR1Y = VR1MAG * VPOLD/VDMAG
C
      VR2X = VRELX - VR1X
      VR2Y = VRELY - VR1Y
      VR2MAG = SQRT (VR2X**2 + VR2Y**2)
C
      FD1 = CD * DENS(SUMASS,TEMP(II,JI)) * 3.14159 * DIAM**2
     1        * VR1MAG**2 /8.
      FD2 = CDINF * DENS(SUMASS,TEMP(II,JI)) * 3.14159 * DIAM**2
     1        * VR2MAG**2 /8.
C
      FD1X = -FD1 * UPOLD/VDMAG
      FD1Y = -FD1 * VPOLD/VDMAG
      FD2X = -FD2 * VR2X/VR2MAG
      FD2Y = -FD2 * VR2Y/VR2MAG
C
      DMASS =  RHOLIQ * DIAM**3 * 3.14159 / 6.
C
      UPNEW = UPOLD + (FD1X + FD2X) / DMASS * DTIME + GRAVX * DTIME
      VPNEW = VPOLD + (FD1Y + FD2Y) / DMASS * DTIME + GRAVY * DTIME
C
C       UPDATE GAS VELOCITY AT NEW POSITION
C
      UGAS = UBDY(II,JI) + (UBDY(II+1,JI) - UBDY(II,JI))
     1                 *(XPNEW - XBDY(II)) / (XBDY(II+1) - XBDY(II))
C
      VGAS = VBDY(II,JI) + (VBDY(II,JI+1) - VBDY(II,JI))
     1                 *(YPNEW - YBDY(JI)) / (YBDY(JI+1) - YBDY(JI))
C
C       UPDATE DROPLET TEMPERATURE AND DIAMETER
C
C       ETAS ACCOUNTS FOR EFFECT OF DROPLET SPACING ON EVAPORATION
C
      ETAS    = 1 - (DIAM/2/SPACE) + (DIAM/2/SPACE)**2
C
C       CASE WHERE DROP IS BOILING
C
      IF(.NOT.BOIL) GO TO 400
C
      CBOIL = 8. * TCONDG(II,JI) / RHOLIQ / CPGAS(II,JI)
     1    * ALOG(1. + TRANSNO)
        DUM2 = (DIAM*DIAM - ETAS * CBOIL * (1. + 0.23 * RENOLD**0.5)
     1         * DTIME)
        DUM3 = DUM2/DINIT/DINIT
        IF(DUM3.GT.1.E-12) GOTO 401
          DIAM = 0.
          GETOUT = .TRUE.
          XPOLD = XPNEW
          YPOLD = YPNEW
          UPOLD = UPNEW
          VPOLD = VPNEW
          TIME  = TIME + DTIME
          IF(INJOUT(3).EQ.1) WRITE(2,402)
402       FORMAT(1X,'DROPLET CONSIDERED EVAPORATED WHEN DIAMETER IS'
     1              ,' 1.E-6 OF INITIAL VALUE')
```

```
          RETURN
401     CONTINUE
        DIAM = DUM2**0.5
        TLNEW = TLIQ
C
C       CASE WHERE DROP TEMPERATURE IS CHANGING
C
400   CONTINUE
      IF(BOIL) GOTO 450
        NUSELT = 2. + 0.6 * (RENOLD**0.5) * (PRANDT**(1./3.))
        DUM3   = 6. *NUSELT *TCONDG(II,JI) /RHOLIQ /DIAM /DIAM /CPLIQ
        TLNEW  = TEMP(II,JI) - (TEMP(II,JI)-TLIQ) * EXP(-DUM3 * DTIME)
C
C       CASE WHERE DROP STARTS BOILING DURING STEP (STARTS TO SHRINK TOO)
C
      IF(TLNEW.LT.TBOIL) GOTO 450
        DUM4 = DTIME
     1         -(1./DUM3)*ALOG((TEMP(II,JI)-TLIQ)/(TEMP(II,JI)-TBOIL))
        CBOIL = 8. * TCONDG(II,JI) / RHOLIQ / CPGAS(II,JI)
     1           * ALOG(1. + TRANSNO )
        DUM2 = (DIAM*DIAM - ETAS * CBOIL * (1. + 0.23 * RENOLD**0.5)
     1            * DUM4)
        DUM3 = DUM2/DINIT/DINIT
        IF(DUM3.GT.1.E-12) GOTO 451
          DIAM = 0.
          GETOUT = .TRUE.
          XPOLD = XPNEW
          YPOLD = YPNEW
          UPOLD = UPNEW
          VPOLD = VPNEW
          TIME  = TIME + DTIME
          IF(INJOUT(3).EQ.1) WRITE(2,402)
          RETURN
451     CONTINUE
        DIAM = DUM2**0.5
        TLNEW = TBOIL
        BOIL = .TRUE.
        WZCOLD = .TRUE.
C
C       TEST FOR VELOCITY CONVERGENCE
C
450   CONTINUE
      DUM1 = ABS(UGAS-UPNEW)
      DUM2 = ABS(VGAS-VPNEW)
      IF(DUM1.GT.TOL1.OR.DUM2.GT.TOL1) GOTO 460
        IF(.NOT.CNVRG) WRITE(2,455) TOL1
455     FORMAT(1X,'DROPLET AT STREAM VELOCITY TO WITHIN ',F10.3,' M/S')
        CNVRG = .TRUE.
460   CONTINUE
C
C       NEW QUANTITIES BECOME OLD FOR NEXT TIMESTEP
C
      XPOLD = XPNEW
      YPOLD = YPNEW
      UPOLD = UPNEW
      VPOLD = VPNEW
      TLIQ  = TLNEW
      TIME  = TIME + DTIME
C
C       DEBUG OUTPUT FOR TIMESTEP
      DUM1 = DIAM * 1.E6
      DUM2 = 1. - (DIAM/DINIT)**3
      DUM3 = CDRE / RENOLD
      MGOAL2 = INT(DUM2/STEPM)
      IF(MGOAL1.NE.MGOAL2) PRTLIN=.TRUE.
      IF(WZCOLD)  PRTLIN = .TRUE.
      IF(PRTLIN.AND.INJOUT(3).EQ.1) WRITE(2,510)II,JI,COUNT2,TIME,XPOLD
     1             ,YPOLD,UPOLD,VPOLD,TLIQ,DUM1,DUM2
510   FORMAT(' ',I3,I3,I5,E10.3,2(F7.4),2(F7.3),F7.1,F8.2,F8.3)
C
      RETURN
      END
C ---------------------------------------------------------------------
      SUBROUTINE SETPRT
C
C     Written by Mark Sheldon for EER, 4/18/85
C
C     PURPOSE:
C       SETPRT (SETup PRinTout) prints variables from main program
C       and from subroutine SETINJ.
C
      LOGICAL*1 CASE(80)
C
      REAL*4    NSTEP , LHELIQ
      INTEGER   RMAX, XMAX, TIMAX, RMAXP, XMAXP
      LOGICAL*1 INCASE
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)  , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/LIQCB/
     1       TBOIL, TLIQ, RHOLIQ, LHELIQ, CPLIQ, HCOMLQ, AFMRAT
C
      COMMON/PARMCB/
     1       NSTEP, DSAFE, TSAFE, ESAFE, TOLI
     2      ,MAXSTP, NRAMP, NDROP, TIMAX
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
C       DEBUG OUTPUT HEADER
C
      WRITE(2,200)
200   FORMAT(' ',' ','*** DROPLET INJECTION MODEL ***',/)
C
      WRITE(2,220)(CASE(I),I=1,70)
```

```
220   FORMAT(1X,70A1)
C
      WRITE(2,240)(INCASE(I),I=1,70)
240   FORMAT(1X,70A1,/)
C
      WRITE(2,241)
241   FORMAT(1X,'NOMENCLATURE:')
C
      WRITE(2,242)
242   FORMAT(4X,'X        = AXIAL  DISTANCE (M)')
C
      WRITE(2,243)
243   FORMAT(4X,'Y        = RADIAL DISTANCE (M)')
C
      WRITE(2,244)
244   FORMAT(4X,'U        = AXIAL  VELOCITY (M/S)')
C
      WRITE(2,245)
245   FORMAT(4X,'V        = RADIAL VELOCITY (M/S)')
C
      WRITE(2,246)
246   FORMAT(4X,'I        = AXIAL  ZONE INDEX')
C
      WRITE(2,247)
247   FORMAT(4X,'J        = RADIAL ZONE INDEX')
C
      WRITE(2,248)
248   FORMAT(4X,'XBDY(I)  = LOCATION OF  LEFT-HAND   BOUNDARY'
     1          ,' OF ZONE I,J')
C
      WRITE(2,249)
249   FORMAT(4X,'YBDY(I)  = LOCATION OF INNER RADIAL BOUNDARY'
     1          ,' OF ZONE I,J')
C
      WRITE(2,250)
250   FORMAT(4X,'UBDY(I,J)= AXIAL  GAS VELOCITY AT BDY'
     1          ,' BETWEEN I,J AND I-1,J')
C
      WRITE(2,251)
251   FORMAT(4X,'VBDY(I,J)= RADIAL GAS VELOCITY AT BDY'
     1          ,' BETWEEN I,J AND I,J-1')
C
      WRITE(2,260)IX,IY
260   FORMAT(1X,/,1X,'SOLUTION GRID: '
     1          ,I3,' AXIAL BY ',I3,' RADIAL ZONES',/)
C
      I1 = IXPLUS
      IF(IYPLUS.GT.IXPLUS) I1=IYPLUS
      DO 300 I = 1,I1
        IF(I.LE.IXPLUS.AND.I.LE.IYPLUS)WRITE(2,320)I,XBDY(I),I,YBDY(I)
320     FORMAT(4X,'XBDY(',I3,') = ',F8.4,5X,'YBDY(',I3,') = ',F8.4)
        IF(I.GT.IXPLUS)WRITE(2,340)I,YBDY(I)
340     FORMAT(4X,25X,'YBDY(',I3,') = ',F8.4)
        IF(I.GT.IYPLUS)WRITE(2,360)I,XBDY(I)
360     FORMAT(4X,'XBDY(',I3,') = ',F8.4)
```

```
300   CONTINUE
C
      WRITE(2,400)(J,J=1,IY)
400   FORMAT(1X,/,1X,'AXIAL GAS VELOCITY AT ZONE BOUNDARIES (M/S):'
     1         ,/,3X,'I:',1X,10(2X,:,'J=',I2,2X))
      DO 420 I = 1, IXPLUS
        WRITE(2,440) I,(UBDY1(I,J),J=1,IY)
440     FORMAT(1X,I3,11(1X,F7.2))
420   CONTINUE
C
      WRITE(2,460)(J,J=1,IYPLUS)
460   FORMAT(1X,/,1X,'RADIAL GAS VELOCITY AT ZONE BOUNDARIES (M/S):'
     1         ,/,3X,'I:',1X,10(2X,:,'J=',I2,2X))
      DO 480 I = 1, IX
        WRITE(2,500) I,(VBDY1(I,J),J=1,IYPLUS)
500     FORMAT(1X,I3,11(1X,F7.2))
480   CONTINUE
C
      WRITE(2,520)
520   FORMAT(1X,/,1X,'INITIAL DROPLET PROPERTIES:')
C
      WRITE(2,540)TLIQ
540   FORMAT(4X,'INITIAL DROP TEMP     (K) = ',F7.1)
C
      WRITE(2,560)TBOIL
560   FORMAT(4X,'LIQUID BOILING TEMP   (K) = ',F7.1)
C
      WRITE(2,580)RHOLIQ
580   FORMAT(4X,'LIQUID DENSITY (KG M**-3) = ',E10.3)
C
      WRITE(2,600)CPLIQ
600   FORMAT(4X,'LIQUID HEAT CAPACITY (M**2 S**-2 K**-1) = ',E10.3)
C
      WRITE(2,620)LHELIQ
620   FORMAT(4X,'LATENT HEAT OF EVAP. (M**2 S**-2)       = ',E10.3/)
C
      WRITE(2,640)
640   FORMAT(1X,'PROGRAM PARAMETERS:')
C
      WRITE(2,660) NDROP
660   FORMAT(4X,'NUMBER OF DROPLETS INJECTED  =',I8)
C
      WRITE(2,680)MAXSTP
680   FORMAT(4X,'MAXIMUM NUMBER OF STEPS IN LOOP, MAXSTP = ',I10)
C
      WRITE(2,700) NRAMP
700   FORMAT(4X,'TIMESTEP SIZE INCREASED OVER ',I4
     1         ,' STEPS, 1ST ZONE')
C
      WRITE(2,720)NSTEP
720   FORMAT(4X,'APPROX. MIN. NO. STEPS IN ZONE,  NSTEP = ',F7.3)
C
      WRITE(2,740)DSAFE
740   FORMAT(4X,'SAFETY FACTOR FOR DRAG TIMESTEP, DSAFE = ',F7.3)
C
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      WRITE(2,760)TSAFE
760   FORMAT(4X,'SAFETY FACTOR FOR TEMP TIMESTEP, TSAFE = ',F7.3)
C
      WRITE(2,780)ESAFE
780   FORMAT(4X,'SAFETY FACTOR FOR EVAP TIMESTEP, ESAFE = ',F7.3)
C
      RETURN
      END
C ------------------------------------------------------------------------
      SUBROUTINE GASPRT
C
C     Written by Mark Sheldon for EER, 4/17/85
C
C     PURPOSE:
C       GASPRT (GAS PRinT) prints the important input and output
C       for subroutine GPROP.
C
      REAL       MDOTIN
      LOGICAL*1 CASE(80), INCASE
      INTEGER   RMAX,XMAX ,RMAXP,XMAXP
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
C
      COMMON/INPUT/
     1      MDOTIN, SUMASS, R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)  , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/GASCB/
     1       CPGAS(XMAX,RMAX), DVISCG(XMAX,RMAX), TCONDG(XMAX,RMAX)
     2       ,F02, FN2, FC02, FH20
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
C       OUTPUT FILE
C
C       OUTPUT HEADER
C
      WRITE(2,99)(CASE(I),I=1,70)
99    FORMAT(1X,/,1X,80A1)
C
      WRITE(2,200)(INCASE(I),I=1,70)
200   FORMAT(1X,70A1)
C
      WRITE(2,220)F02,FN2,FC02,FH20
220   FORMAT(1X,/,1X,'MASS FRACTIONS:',/,1X
     1      ,'02=',F6.4,3X,'N2=',F6.4,3X,'C02=',F6.4,3X,'H20=',F6.4)
C
C       INPUT ARRAYS
      WRITE(2,300)(J,J=1,IY)
300   FORMAT(1X,/,1X,'ZONE TEMPERATURE:',/,1X,'I:',1X
    1           ,10(2X,:,'J=',I2,1X))
C
      DO 350 I = 1, IX
        WRITE(2,360) I,(TEMP(I,J),J=1,IY)
360     FORMAT(1X,I3,10(1X,F6.1))
350   CONTINUE
C
C       OUTPUT ARRAYS
C
      WRITE(2,400)(J,J=1,IY)
400   FORMAT(1X,/,1X,'ZONE HEAT CAPACITY (M*M/S/S/K):'
    1           ,/,1X,'I:',1X,10(1X,:,2X,'J=',I2,2X))
C
      DO 410 I = 1, IX
        WRITE(2,420) I,(CPGAS(I,J),J=1,IY)
420     FORMAT(1X,I3,10(1X,F8.1))
410   CONTINUE
C
      WRITE(2,500)(J,J=1,IY)
500   FORMAT(1X,/,1X,'ZONE DYNAMIC VISCOSITY (KG/M/S):'
    1           ,/,1X,'I:',1X,10(4X,:,'J=',I2,4X))
C
      DO 510 I = 1, IX
        WRITE(2,520) I,(DVISCG(I,J),J=1,IY)
520     FORMAT(1X,I3,10(1X,E11.4))
510   CONTINUE
C
      WRITE(2,600)(J,J=1,IY)
600   FORMAT(1X,/,1X,'ZONE THERMAL CONDUCTIVITY (KG/S/S/S/K):'
    1           ,/,1X,'I:',1X,10(4X,:,'J=',I2,4X))
C
      DO 610 I = 1, IX
        WRITE(2,620) I,(TCONDG(I,J),J=1,IY)
620     FORMAT(1X,I3,10(1X,F11.6))

610   CONTINUE
C
      RETURN
      END
C -----------------------------------------------------------------------
      SUBROUTINE DRPPRT
C
C     Written by Mark Sheldon for EER, 4/18/85
C
C     PURPOSE:
C       DRPPRT (DRoPlet PRinTout) prints variables from subroutines
C       DROP and SPRAY.
C
      LOGICAL*1 CASE(80), INCASE
      INTEGER   RMAX,XMAX ,RMAXP,XMAXP
      PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26)
      REAL*4    LOD
C
      COMMON/DROPCB/
     1     XPOLD, YPOLD, UPOLD, VPOLD, DRPVEL, DINIT, LOD, IT
     2      ,XPINIT, YPINIT, UPINIT, VPINIT, SPACIN, SPACE, VINIT1
C
      COMMON/PRTCB/
     1      CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2      ,NPRT1, NPRT2, NPRT3
C
      COMMON/LIQCB/
     1      TBOIL, TLIQ, RHOLIQ, LHELIQ, CPLIQ, HCOMLQ, AFMRAT
C
C       DEBUG OUTPUT HEADER
C
      WRITE(2,110)(CASE(I),I=1,70)
110   FORMAT(1X,/,1X,70A1)
C
      WRITE(2,120)(INCASE(I),I=1,70)
120   FORMAT(1X,70A1)
C
      IF(INJOUT(5).EQ.1)WRITE(2,125)
125   FORMAT(1X,/,1X,'GRAVITY INCLUDED IN THE POSITIVE X DIRECTION')
C
      IF(INJOUT(6).EQ.1)WRITE(2,126)
126   FORMAT(1X,/,1X,'GRAVITY INCLUDED IN THE POSITIVE Y DIRECTION')
C
      WRITE(2,160) AFMRAT
160   FORMAT(4X,'AIR/FUEL MASS RATIO =',F10.4)
C
      WRITE(2,220)
220   FORMAT(1X,/,1X,'DROPLET INITIAL CONDITIONS:')
C
      WRITE(2,230) DINIT
230   FORMAT(4X,'INITIAL DROP DIAMETER (M) = ',E10.3)
C
      WRITE(2,240) XPINIT, YPINIT
240   FORMAT(4X,'INITIAL POSITION: X (M)  =',F10.3,' Y (M)  =',F10.3)
C
      WRITE(2,250) UPINIT, VPINIT
250   FORMAT(4X,'INITIAL VELOCITY: U (M/S)=',F10.3,' V (M/S)=',F10.3)
C
      WRITE(2,260) LOD
260   FORMAT (4X,'INITIAL L/D               = ',F10.2)
C
      WRITE(2,270) SPACIN
270   FORMAT (4X,'INITIAL SPACING BETWEEN DROPLETS (M) = ',E10.3)
C
      WRITE(2,290)
290   FORMAT(1X,'DROP TIME HISTORY')
C
      WRITE(2,310)
310   FORMAT(' ',/,' ','      STEP          POSITION (M)  VELOCITY'
     1           ,' (M/S)  LIQ   DIAM-    MASS')
C
      WRITE(2,320)
320   FORMAT(' ',' ZONE  # IN   TIME    AXIAL  RADIAL  AXIAL RADIAL'
     1         ,'  TEMP    ETER    FRAC')
C
```

```
      WRITE(2,330)
330   FORMAT(1X,'I    J  ZONE   (SEC)     X       Y       U      V'
     1         ,'      (K)    (MU)    EVAP')
C
      RETURN
      END
C-------------------------------------------------------------------
      SUBROUTINE INJPRT
C
C     PURPOSE:
C       "INJPRT" stands for:
C
          LOGICAL*1 CASE(60), INCASE
          INTEGER   TIMAX,  DSTMAX, DST2(50,20), DSTRIB
          REAL      LOD
          INTEGER   RMAXP, XMAXP, ONE, TWO, RMAX, XMAX
C
          PARAMETER (RMAX=15,XMAX=25,RMAXP=16,XMAXP=26,ONE=10,TWO=50)
C
      COMMON/ZBDYCB/
     1       UBDY(XMAXP,RMAX), VBDY(XMAX,RMAXP),UBDY1(XMAXP,RMAX)
     2      ,XBDY(XMAXP)  , YBDY(RMAXP)        ,VBDY1(XMAX,RMAXP)
     3      ,TWALL(XMAX,RMAX), IX, IY, IXPLUS, IYPLUS
C
      COMMON/INPUT/
     1     MDOTIN, SUMASS ,R(RMAX), TEMP(XMAX,RMAX), XL(XMAX), II, JI
C
      COMMON/PRTCB/
     1       CASE, INCASE(80), INJOUT(10), INPTYP(10)
     2       ,NPRT1, NPRT2, NPRT3
C
      COMMON/PRINT/
     1     DSTRIB(ONE,TWO),DSTMAX,NXMAX,NYMAX,XMEAN,YMEAN,XFINAL,YFINAL
     2     ,XMX,YMAX,XMIN,YMIN,STDVX,STDVY,NXGRID,NYGRID
C
      COMMON/DROPCB/
     1       XPOLD, YPOLD, UPOLD, VPOLD, DRPVEL, DINIT, LOD, IT
     2      ,XPINIT, YPINIT, UPINIT, VPINIT, SPACIN, SPACE, VINIT1
C
C     OUTPUT -  PRINT INITIAL CONDITIONS AND STATISTICS
C
      WRITE(7,100)
100   FORMAT(1X,/,1X,'INJECTION RESULTS:',/)
C
      WRITE(7,105)(CASE(I),I=1,60)
105   FORMAT(1X,60A1)
      WRITE(7,110)(INCASE(I),I=1,70)
110   FORMAT(1X,70A1)
      WRITE(7,120)
120   FORMAT(1X,/,1X,'DROPLET INITIAL CONDITIONS:')
C
      WRITE(7,130)DINIT
130   FORMAT(4X,'INITIAL DROP DIAMETER (M) = ',E10.3)
C
      WRITE(7,140)XPINIT,YPINIT
```

```
140   FORMAT(4X,'INITIAL POSITION: X (M)  =',F8.3
     1          ,'  Y (M)  =',F8.3)
C
      WRITE(7,150)UPINIT,VPINIT
150   FORMAT(4X,'INITIAL VELOCITY: U (M/S)=',F8.3
     1          ,'  V (M/S)=',F8.3/)
C
      WRITE (7,160) DRPVEL,LOD,SPACIN
160   FORMAT(4X,'INITIAL TOTAL VELOCITY (M/S) =',F10.3/4X,
     1        'INITIAL SPACING = ',F9.3,' DROPLET DIAMETERS'/4X,
     2        'INITIAL SPACING BETWEEN DROPLETS  = ',E10.3)
C
      WRITE(7,170) TIMAX,XMEAN,YMEAN
170   FORMAT(/2X,'THE DATA CONTAINS ',I4,' DATA POINTS, WITH THE ',
     1 'AVERAGE EVAPORATION POINT'/2X,'LOCATED AT (',F5.3,',',F5.3,
     2 ').')
      WRITE(7,180) STDVX,STDVY
180   FORMAT (2X,'THE STANDARD DEVIATIONS ARE (',F5.3,',',F5.3,
     1           ')')
      WRITE(7,190) XMIN,XMX,YMIN,YMAX
190   FORMAT (2X,'THE RANGES IN BOTH DIRECTIONS ARE ',
     1     'X: (',F5.3,'-',F5.3,')'/36X,'Y: (',F5.3,'-',F5.3,')')
      WRITE(7,200) NXGRID,NYGRID,XFINAL,YFINAL
200   FORMAT(2X,'IN THIS GRID, GRID POINTS X = ',I2,' AND Y = ',
     1   I2,/2X,'CORRESPOND'
     2   ,' TO THE PHYSICAL LOCATION (',F5.3,',',F5.3,').')
C
      N = 1
      NP = 20
      WRITE(7,230)
 230  FORMAT(/25X,'DISTRIBUTION OF DROPLET EVAPORATION')
 240  WRITE(7,250) (J,J=N,NP)
 250  FORMAT(/7X,'X',20I4,/4X,'Y')
      DO 280 J = 1,NYMAX
      WRITE(7,260) J,(DSTRIB(I,J),I=N,NP)
 260  FORMAT(3X,I2,3X,20I4)
      DO 270 I = N,NP
      DST2(I,J) = INT(FLOAT(DSTRIB(I,J)) * 10. /FLOAT(DSTMAX))
 270  CONTINUE
 280  CONTINUE
      N = N + 20
      NP = NP + 20
      IF (N.GT.NXMAX) GO TO 290
      GO TO 240
C
 290  N = 1
      NP = 20
      WRITE(7,300)
 300  FORMAT(/20X,'NORMALIZED DISTRIBUTION DENSITY RANGING FROM 1 - 10')
 310  WRITE(7,320) (J,J=N,NP)
 320  FORMAT(/7X,'X',20I4,/4X,'Y')
      DO 340 J = 1,NYMAX
      WRITE(7,330) J,(DST2(I,J),I=N,NP)
 330  FORMAT(3X,I2,3X,20I4)
 340  CONTINUE
```

```
      N = N + 20
      NP = NP + 20
      IF(N.GT.NXMAX) GO TO 350
      GO TO 310
C
 350  RETURN
      END
```

```
C                            DROP3D
C     PROGRAM ICMINC
C
C     Written by Wyman Clark, modified by Mark Sheldon 4/30/85
C
C     PURPOSE:
C       "ICMINC" stands for
C       "Incinerator Cylindrical 3-d model, Main INCinerator code"
C
C***** DECLARATIONS
C
          LOGICAL*1 LABEL(70,10)
          REAL      MDOTIN
          INTEGER     TIMAX, INJOUT, INPTYP
          LOGICAL*1   COMPND(40,20), CASE(60), INCASE
C
      COMMON/DIMCB/
     1       IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
      COMMON/PRTCB/
     1       CASE  , INCASE(80)    , INJOUT(10), INPTYP(10)
     2      ,NPRT1 , NPRT2 , NPRT3
C
      COMMON/INPUT/
     3           V(25,15,5),   TEMP(25,15,5), MDOTIN
     4      ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC  , NPART
     5      ,II    , JI    , KI    , NCMPND, COMPND, JRAND
C
      COMMON/BDYCB/
     1       XL(25)    , XBDY(26)  , UBDY(26,15,5), UBDY1(26,15,5)
     2      ,R(15)     , YBDY(16)  , VBDY(25,16,5), VBDY1(25,16,5)
     3      ,DTHETA(5) , ZBDY(6)   , WBDY(25,15,6), WBDY1(25,15,6)
     4      ,ROTBDY(25,15,6), TWALL(25,15,5) , CYL
C
      COMMON/GASCB/
     1       CPGAS(25,15,5) , DVISCG(25,15,5), TCONDG(25,15,5)
     2      ,FO2   , FN2   , FCO2  , FH2O
C
C***** END OF DECLARATIONS
C
      OPEN(UNIT=5,FILE='DROP3D.DAT')
C
C      INPUT TEST CONDITIONS:
C                     CASE NAME,CASE
C                     NUMBER OF ZONES PER COORDINATE: IX,IY,IZ
C                     ZONE DIMENSIONS: XL, R, DTHETA
C                     INPUT MASS FLOW,MDOTIN (KG/SEC)
C                     MASS FRACTION (WET, ASH) CO2,H2O,N2,O2
C                     RELATIVE MASS FLOWS,MDOTxx (INPUT=1 BASIS)
C                     ZONE GAS TEMPERATURES,TEMP
C
C     CASE TITLE
C
      READ(5,100)(CASE(I),I=1,60)
100   FORMAT(80A1)
```

```
C
C     ARRAY DIMENSIONS
C
      READ(5,200)IX,IY,IZ
200   FORMAT(3X,3(I4,5X))
C
C     ZONE DIMENSIONS AND VOLUMES
C
      I1 = 1
      I2 = 5
      DO 310 L = 1,IX
        IF(IX.LT.I2) I2 = IX
        READ(5,320)(XL(I),I=I1,I2)
320     FORMAT(15X,5(1X,F8.4))
        I1 = I2 + 1
        I2 = I1 + 4
        IF(I1.GT.IX) GOTO 340
310   CONTINUE
340   CONTINUE
C
      I1 = 1
      I2 = 5
      DO 350 L = 1,IY
        IF(IY.LT.I2) I2 = IY
        READ(5,320)(R(J),J=I1,I2)
        I1 = I2 + 1
        I2 = I1 + 4
        IF(I1.GT.IY) GOTO 370
350   CONTINUE
370   CONTINUE
C
      I1 = 1
      I2 = 5
      DO 380 L = 1,IZ
        IF(IZ.LT.I2) I2 = IZ
        READ(5,320)(DTHETA(K),K=I1,I2)
        I1 = I2 + 1
        I2 = I1 + 4
        IF(I1.GT.IZ) GOTO 400
380   CONTINUE
400   CONTINUE
C
C     MASS FLOWRATE AND MASS FRACTIONS
C
      READ(5,500)MDOTIN
500   FORMAT(8X,F8.5)
C
      READ(5,520)FCO2,FH2O,FN2,FO2
520   FORMAT(4(6X,F8.5))
C
      SUMASS=(FCO2/.044)+(FH2O/.018)+(FN2/.028)+(FO2/.032)
C
C     VELOCITIES IN THE AXIAL DIRECTION
C
      IXPLUS = IX+1
      READ(5,100)(LABEL(I,1),I=1,70)
      DO 610 I=1,IXPLUS
         I1=1
         I2=8
         DO 620 L=1,IX
           IF(IY.LT.I2) I2=IY
           READ(5,600)(UBDY1(I,J,1),J=I1,I2)
 600  FORMAT(8F8.4)
           I1=I2+1
           I2=I1+7
           IF(I1.GT.IY) GO TO 610
 620    CONTINUE
 610   CONTINUE
C
C    VELOCITIES IN THE RADIAL DIRECTION
C
       IYPLUS=IY+1
       READ(5,100)(LABEL(I,2),I=1,70)
       DO 630 I=1,IX
         I1=1
         I2=8
         DO 640 L=1,IX
           IF(IYPLUS.LT.I2) I2=IYPLUS
           READ(5,625) (VBDY1(I,J,1),J=I1,I2)
 625  FORMAT(8F8.4)
           I1=I2+1
           I2=I1+7
           IF(I1.GT.IYPLUS) GO TO 632
 640     CONTINUE
 632   CONTINUE
 630   CONTINUE
C
      IZPLUS=IZ+1
      READ(5,100)(LABEL(I,6),I=1,70)
      DO 690 K = 1,IZPLUS
      DO 700 I = 1,IX
         I1=1
         I2=8
         DO 710 L=1,IX
           IF(IY.LT.I2) I2=IY
           READ(5,600)(WBDY1(I,J,K),J=I1,I2)
           I1=I2+1
           I2=I1+7
           IF(I1.GT.IY) GO TO 700
 710       CONTINUE
 700    CONTINUE
 690   CONTINUE
C
C     GAS TEMPERATURES
C
      READ(5,100)(LABEL(I,7),I=1,70)
      DO 910 K=1,IZ
      DO 910 I=1,IX
        I1=1
        I2=8
```

```
          DO 925 L=1,IY
          IF(IY.LT.I2) I2=IY
          READ(5,920)(TEMP(I,J,K),J=I1,I2)
920       FORMAT(8F8.2)
          I1=I2+1
          I2=I1+7
          IF(I1.GT.IY) GO TO 915
925     CONTINUE
 915    CONTINUE
910    CONTINUE
C
C      CONCLUDE INPUT AND CALL INJECTION MODEL
C
       CALL ICSINJ
       CLOSE(UNIT=5)
       STOP
       END
C ----------------------------------------------------------------------
       SUBROUTINE ICSINJ
C
C      Modified from INJECT by Mark Sheldon for EER, 4/30/85
C
C      PURPOSE: "ICSINJ" stands for:
C        "Incineration Cylindrical 3-d model,
C          Subroutine for INJection"
C
C      SUBROUTINES CALLED BY ICSINJ      (SOME INDIRECTLY):
C        ICSSET   Calculates data (except gas prop) for other routines
C        ICSGAS   Calculates gas properties ( Cp, Visc, Therm. Cond.)
C        ICSDRP   Sends droplet through incinerator, zozone by zone
C        ICSSPR   Gives initial conditions to each droplet
C        ICSMOV   Trajectory/heating/evaporation of drop in 1 timestep
C        ICPSET   Output header from ICSINJ
C        ICPGAS   Output header from ICSGAS
C        ICPSPR   Output header from ICSDRP and/or ICSSPR
C        ICPINJ   Output header from ICSINJ (final results)
C
           REAL         MDOTIN, LHELIQ, NOZDIA, KNOZ
           INTEGER      TIMAX, DSTMAX, DSTRIB
           LOGICAL*1    COMPND(40,20), CASE(60), INCASE
           LOGICAL      BOIL, CNVRG, GETOUT
C
        COMMON/DIMCB/
     1        IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
        COMMON/LIQCB/
     1        TBOIL , TLIQ  , RHOLIQ, LHELIQ, CPLIQ, HCOMLQ
C
        COMMON/NOZCB/
     1        NOZDIA, AFMRAT, KNOZ  , XNOZ  , YNOZ  , ZNOZ
     2       ,UPCOMP, VPCOMP, WPCOMP, UNOZ
C
        COMMON/PARMCB/
     1        ZSAFE , DSAFE , TSAFE , ESAFE , TOL1
     2       ,NDROP , MAXSTP, NRAMP
```

```
C
      COMMON/PRTCB/
     1        CASE   , INCASE(80)     , INJOUT(10), INPTYP(10)
     2       ,NPRT1  , NPRT2  , NPRT3
C
      COMMON/MOVECB/
     1        DTIME  , DTSAV  , OLDDT  , TIME   , PATH   , DIAM
     2       ,UGAS   , VGAS   , WGAS   , IINEW  , JINEW  , KINEW
     3       ,ICNT1  , ICNT2  , PRANDT, BOIL   , CNVRG  , GETOUT
C
      COMMON/INPUT/
     3            V(25,15,5),   TEMP(25,15,5), MDOTIN
     4       ,SUMASS, TIMAX  , TEMAX  , TEMIN  , TAUC   , NPART
     5       ,II     , JI     , KI     , NCMPND, COMPND, JRAND
C
      COMMON/BDYCB/
     1        XL(25)     , XBDY(26)   , UBDY(26,15,5), UBDY1(26,15,5)
     2       ,R(15)      , YBDY(16)   , VBDY(25,16,5), VBDY1(25,16,5)
     3       ,DTHETA(5)  , ZBDY(6)    , WBDY(25,15,6), WBDY1(25,15,6)
     4       ,ROTBDY(25,15,6), TWALL(25,15,5) , CYL
C
      COMMON/GASCB/
     1        CPGAS(25,15,5) , DVISCG(25,15,5), TCONDG(25,15,5)
     2       ,FO2    , FN2    , FCO2   , FH2O
C
      COMMON/DROPCB/
     1        XPOLD, YPOLD, ZPOLD, UPOLD, VPOLD, WPOLD, DRPVEL
     2        XPINIT, YPINIT, ZPINIT, UPINIT, VPINIT, WPINIT
     3       ,DINIT , RNDNUM, SPACIN, C, SPACE, IT
C
      COMMON/PRINT/
     1        DSTRIB(50,20), DSTMAX, NXMAX, NYMAX, XMEAN, YMEAN, ZMEAN
     2        , XFINAL, YFINAL, NXGRID, NYGRID, STDVX, STDVY, STDVZ
     3        , XMAX, YMAX, ZMAX, XMIN, YMIN, ZMIN
C
C     DATA INITIALIZATION
C
C     OUTPUT FILE
C
      OPEN(UNIT=6,FILE='DROP3D.OUT')
C
C     SET INCINERATOR CONDITIONS
C
      CALL ICSSET
      CALL ICSGAS
C
C     INITIAL LIQUID TEMPERATURE (ASSUMED SAME FOR ALL DROPS)
C
      TINIT = TLIQ
C
C     INJECT DROPS AND TALLY THE ENDPOINT DISTRIBUTION
C
      IF(INJOUT(3).EQ.1) INJFL3 = 1
      DO 3000 M = 1,NDROP
      XSUM = 0
      YSUM = 0
      ZSUM = 0
      XSQSUM = 0
      YSQSUM = 0
      ZSQSUM = 0
      DO 10 I=1,20
      DO 10 J=1,20
      DSTRIB(I,J) = 0
 10   CONTINUE
      IF (INJFL3.EQ.1) INJOUT(3) = 1
C
      IF(INPTYP(6).EQ.1) GO TO 1100
      DO 1000 IT = 1,TIMAX
        IF(IT.GT.NPRT3) INJOUT(3)=0
        TLIQ = TINIT
        XPOLD = XPINIT
        YPOLD = YPINIT
        ZPOLD = ZPINIT
        UPOLD = UPINIT
        VPOLD = VPINIT
        WPOLD = WPINIT
        DO 540 I = 1,IX
        DO 530 J = 1,IY
        DO 520 K = 1,IZ
        VMAG = SQRT(UBDY1(I,J,K)**2 + VBDY1(I,J,K)**2 + WBDY1(I,J,K)**2)
        IF( VMAG.LE.7.62)  SIGMAX = 1.524
        IF( VMAG.LE.7.62)  SIGMAY = 3.048
        IF( VMAG.LE.7.62)  SIGMAZ = 1.524
        IF(VMAG.GT.15.24) SIGMAX = 0.6096
        IF(VMAG.GT.15.24) SIGMAY = 0.9144
        IF(VMAG.GT.15.24) SIGMAZ = 0.6096
        IF(VMAG.GT.7.62.AND.VMAG.LE.15.24) SIGMAX = 1.524
        IF(VMAG.GT.7.62.AND.VMAG.LE.15.24) SIGMAY = 3.048
        IF(VMAG.GT.7.62.AND.VMAG.LE.15.24) SIGMAZ = 1.524
        CALL RANDOM(STDDEV,N)
        UBDY(I,J,K) = UBDY1(I,J,K) + STDDEV * SIGMAX * N
        CALL RANDOM (STDDEV,N)
        VBDY(I,J,K) = VBDY1(I,J,K) + STDDEV * SIGMAY * N
        CALL RANDOM (STDDEV,N)
        WBDY(I,J,K) = WBDY1(I,J,K) + STDDEV * SIGMAZ * N
  520 CONTINUE
  530 CONTINUE
  540 CONTINUE
C
        CALL ICSDRP
C
      XSUM = XSUM + XPOLD
      YSUM = YSUM + YPOLD
      ZSUM = ZSUM + ZPOLD
      XSQSUM = XSQSUM + XPOLD **2
      YSQSUM = YSQSUM + YPOLD **2
      ZSQSUM = ZSQSUM + ZPOLD **2
      IF (XPOLD.GT.XMAX) XMAX = XPOLD
      IF (YPOLD.GT.YMAX) YMAX = YPOLD
      IF (ZPOLD.GT.ZMAX) ZMAX = ZPOLD
      IF (XPOLD.LT.XMIN) XMIN = XPOLD
      IF (YPOLD.LT.YMIN) YMIN = YPOLD
      IF (ZPOLD.LT.ZMIN) ZMIN = ZPOLD
      IF (IT.LT.TIMAX) GO TO 200
C
C     STATISTICAL CALCULATIONS
C
        XMEAN = XSUM/TIMAX
        YMEAN = YSUM/TIMAX
        ZMEAN = ZSUM/TIMAX
        STDVX = SQRT(ABS((XSQSUM * TIMAX - XSUM**2)/TIMAX/(TIMAX-1)))
        STDVY = SQRT(ABS((YSQSUM * TIMAX - YSUM**2)/TIMAX/(TIMAX-1)))
        STDVZ = SQRT(ABS((ZSQSUM * TIMAX - ZSUM**2)/TIMAX/(TIMAX-1)))
C
200   IF(IT.GT.2) GO TO 101
       XFINAL = XPOLD
       YFINAL = YPOLD
       ZFINAL = ZPOLD
       XMIN = XPOLD
       YMIN = YPOLD
       ZMIN = ZPOLD
       INTX = INT(XPOLD * 100.)
       INTY = INT(YPOLD * 100)
       NXGRID = 10
       NYGRID = 6
        IF(INTX.LT.15) NXGRID = INTX
        IF(INTY.LT.5) NYGRID = INTY
C
C     TALLY LOCATION OF X COORDINATE IN FINAL GRID
C
 101  IF(XPOLD.GE.XFINAL) GO TO 103
        IADDX = INT(INTX - XPOLD * 100) + 1
        NX = NXGRID - IADDX
        IF (NX.GE.1) GO TO 102
         NXA = IABS(NX) + 1
         NXMAXP = NXMAX + NXA
         NXAP = NXA + 1
         NDIF = NXMAXP - NXAP
         DO 1 JI = 1,NDIF
          I = NXMAXP - JI
          IDUM = I - NXA
          DO 1 J = 1,NYMAX
          DSTRIB(I,J) = DSTRIB(IDUM,J)
          DSTRIB(IDUM,J) = 0
    1    CONTINUE
          NX = 1
          NXMAX = NXMAXP
          NXGRID = NXGRID + NXA
       GO TO 102
 103    IADDX = INT(XPOLD*100 - INTX)
        NX = NXGRID + IADDX
        IF (NX.GT.NXMAX) NXMAX = NX
C
C     TALLY LOCATION OF Y COORDINATE IN FINAL GRID
C
```

```
  102 IF(YPOLD.GE.YFINAL) GO TO 105
         IADDY = INT(INTY - YPOLD * 100) + 1
         NY = NYGRID - IADDY
         IF(NY.GE.1) GO TO 104
C
C        SHIFT ENTIRE GRID AND PREVIOUSLY COUNTED POINTS
C
           NYA = IABS(NY) + 1
           NYMAXP = NYMAX + NYA
           NYAP = NYA + 1
           NDIF = NYMAXP - NYAP
           DO 2 JI=1,NDIF
           J = NYMAXP - JI
           IDUM = J - NYA
           DO 2 I = 1,NXMAX
           DSTRIB(I,J) = DSTRIB(I,IDUM)
           DSTRIB(I,IDUM) = 0
    2      CONTINUE
           NY = 1
           NYMAX = NYMAXP
           NYGRID = NYGRID + NYA
          GO TO 104
  105      IADDY = INT(YPOLD * 100 - INTY)
           NY = NYGRID + IADDY
           IF (NY.GT.NYMAX) NYMAX = NY
C
  104    DSTRIB(NX,NY) = DSTRIB(NX,NY) + 1
         IF (DSTRIB(NX,NY).GT.DSTMAX) DSTMAX = DSTRIB(NX,NY)
        WRITE(6,900) XPOLD,YPOLD,NX,NY,DSTRIB(NX,NY),DSTMAX
  900   FORMAT (3X,'XPOLD =',F5.3,'  YPOLD =',F5.3/
     1          3X,'DSTRIB(',I2,',',I2,') = ',I2,3X,'DSTMAX =',I5/)
 1000    CONTINUE
         GO TO 2000
C
C        CASE WITH NO TURBULENCE
C
 1100   TLIQ = TINIT
          IT =1
          XPOLD = XPINIT
          YPOLD = YPINIT
          ZPOLD = ZPINIT
          UPOLD = UPINIT
          VPOLD = VPINIT
          WPOLD = WPINIT
        DO 1110 I = 1,IX
        DO 1120 J = 1,IY
        DO 1130 K = 1,IZ
        UBDY(I,J,K) = UBDY1(I,J,K)
        VBDY(I,J,K) = VBDY1(I,J,K)
        WBDY(I,J,K) = WBDY1(I,J,K)
 1130   CONTINUE
 1120   CONTINUE
 1110   CONTINUE
         INJOUT(4) = 0
         CALL ICSDRP
```

```
C
2000  CONTINUE
C
C     OUTPUT RESULTS OF INJECTION MODEL
C
      OPEN(UNIT=7,FILE='STAT.OUT')
      IF(INJOUT(4).EQ.1) CALL ICPINJ
C
3000  CONTINUE
      CLOSE(UNIT=6)
      CLOSE(UNIT=7)
      RETURN
      END
C ---------------------------------------------------------------------
      SUBROUTINE RANDOM(STDDEV,N)
      INTEGER IA(55),START1,START2
      REAL X(500)
C
C     THIS SUBROUTINE GENERATES RANDOM NUMBERS BETWEEN 0 AND 1000
C     AND THEN INSTITUTES A GAUSSIAN DISTRIBUTION FROM THE RANDOM OUTPUT.
C     THE PRIMARY REFERENCE IS FOR THE RANDOM NUMBER GENERATOR IS:
C
C                R. Rouse and T. Bugnitz
C                Programming the IBM Personal Computer: Fortran 77
C                Holt, Rhinehart, and Winston , 1983
C
C      COMMON/INPUT/
     1           V(25,15,1),   TEMP(25,15,1), MDOTIN
     2      ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC   , NPART
     3      ,II    , JI    , KI    , NCMPND, COMPND, JRAND
C
C       D IS RANDOM NUMBER BETWEEN 0 AND 1000
C
      CALL GETTIM (I1,I2,I3,I4)
      START1 = ( I1 + I2 + I3 + I4 ) * 1000
      CALL IN55(IA,START1)
      JRAND = JRAND + 1
      IF (JRAND.GT.55) JRAND = IRN55(IA)
      D = FLOAT (IA(JRAND)) * 1.0E-9 * 1000
      N = -1
      IF (D.GT.500) N = 1
      IF (D.GT.500) D = D - 500.
C
      IF(D.LT.20.9) STDDEV=0
      IF(D.GE.20.9.AND.D.LT.60.6) STDDEV = 0.1
      IF(D.GE.60.6.AND.D.LT.99.7) STDDEV = 0.2
      IF(D.GE.99.7.AND.D.LT.137.8) STDDEV = 0.3
      IF(D.GE.137.8.AND.D.LT.174.7) STDDEV = 0.4
      IF(D.GE.174.7.AND.D.LT.209.9) STDDEV = 0.5
      IF(D.GE.209.9.AND.D.LT.243.2) STDDEV = 0.6
      IF(D.GE.243.2.AND.D.LT.274.4) STDDEV = 0.7
      IF(D.GE.274.4.AND.D.LT.303.4) STDDEV = 0.8
      IF(D.GE.303.4.AND.D.LT.330.0) STDDEV = 0.9
      IF(D.GE.330.0.AND.D.LT.354.2) STDDEV = 1.0
      IF(D.GE.354.2.AND.D.LT.376.0) STDDEV = 1.1
      IF(D.GE.376.0.AND.D.LT.395.4) STDDEV = 1.2
      IF(D.GE.395.4.AND.D.LT.412.6) STDDEV = 1.3
      IF(D.GE.412.6.AND.D.LT.427.5) STDDEV = 1.4
      IF(D.GE.427.5.AND.D.LT.440.5) STDDEV = 1.5
      IF(D.GE.440.5.AND.D.LT.451.6) STDDEV = 1.6
      IF(D.GE.451.6.AND.D.LT.461.0) STDDEV = 1.7
      IF(D.GE.461.0.AND.D.LT.468.9) STDDEV = 1.8
      IF(D.GE.468.9.AND.D.LT.475.4) STDDEV = 1.9
      IF(D.GE.475.4.AND.D.LT.480.8) STDDEV = 2.0
      IF(D.GE.480.8.AND.D.LT.485.2) STDDEV = 2.1
      IF(D.GE.485.2.AND.D.LT.488.4) STDDEV = 2.2
      IF(D.GE.488.4.AND.D.LT.491.6) STDDEV = 2.3
      IF(D.GE.491.6.AND.D.LT.494.0) STDDEV = 2.4
      IF(D.GE.494.0.AND.D.LT.495.8) STDDEV = 2.5
      IF(D.GE.495.8.AND.D.LT.497.2) STDDEV = 2.6
      IF(D.GE.497.2.AND.D.LT.498.2) STDDEV = 2.7
      IF(D.GE.498.2.AND.D.LT.499.0) STDDEV = 2.8
      IF(D.GE.499.0.AND.D.LT.499.6) STDDEV = 2.9
      IF(D.GE.499.6.AND.D.LT.500.0) STDDEV = 3.0
      RETURN
      END
C
C  ------------------------------------------
C
C        PROGRAM TO INITIALIZE IA
C
      SUBROUTINE IN55(IA,IX)
      INTEGER IA(1),IX,I,J,K,II
      IA(55) = IX
      J = IX
      K = I
      DO 1 I = 1,54
       II = MOD(21*I,55)
       IA(II) = K
       K = J - K
       IF (K.LT.0) K = K + 1000000000
       J = IA(II)
 1    CONTINUE
C
      I = IRN55(IA)
      I = IRN55(IA)
      I = IRN55(IA)
      RETURN
       END
C
C          FUNCTION SUBPROGRAM TO GENERATE RANDOM NUMBERS
C
      FUNCTION IRN55(IA)
      INTEGER IA(1),I,J
      DO 1 I = 1,24
        J = IA(I) - IA(I + 31)
        IF(J.LT.0) J = J + 1000000000
        IA(I) = J
 1    CONTINUE
C
```

```
      DO 2 I = 25,55
        J = IA(I) - IA(I - 24)
        IF(J.LT.0) J = J + 1000000000
        IA(I) = J
  2   CONTINUE
      IRN55 = 1
      RETURN
      END
C -------------------------------------------------------------------
      SUBROUTINE   ICSSET
C
C     Modified from SETINJ by Mark Sheldon for EER, 4/30/85
C
C     PURPOSE:  "ICSSET" Stands for:
C       "Incineration, Cylindrical 3-d model,
C         Subroutine for SETup"
C
          REAL          MDOTIN, LHELIQ, NOZDIA, KNOZ
          INTEGER       TIMAX
          LOGICAL*1     COMPND(40,20),CASE(60), INCASE
          LOGICAL       CYL
C
      COMMON/DIMCB/
     1        IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
      COMMON/LIQCB/
     1        TBOIL , TLIQ  , RHOLIQ, LHELIQ, CPLIQ, HCOMLQ
C
      COMMON/NOZCB/
     1        NOZDIA, AFMRAT, KNOZ  , XNOZ  , YNOZ  , ZNOZ
     2       ,UPCOMP, VPCOMP, WPCOMP, UNOZ
C
      COMMON/PARMCB/
     1        ZSAFE , DSAFE , TSAFE , ESAFE , TOL1
     2       ,NDROP , MAXSTP, NRAMP
C
      COMMON/PRTCB/
     1        CASE  , INCASE(80)    , INJOUT(10), INPTYP(10)
     2       ,NPRT1 , NPRT2 , NPRT3
C
      COMMON/INPUT/
     3             V(25,15,5),   TEMP(25,15,5), MDOTIN
     4       ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC  , NPART
     5       ,II    , JI    , KI    , NCMPND, COMPND, JRAND
C
      COMMON/BDYCB/
     1        XL(25)    , XBDY(26)  , UBDY(26,15,5), UBDY1(26,15,5)
     2       ,R(15)     , YBDY(16)  , VBDY(25,16,5), VBDY1(25,16,5)
     3       ,DTHETA(5) , ZBDY(6)   , WBDY(25,15,6), WBDY1(25,15,6)
     4       ,ROTBDY(25,15,6), TWALL(25,15,5) , CYL
C
      COMMON/SWRLCB/
     1        CFORCE(25,15,6), CFREE(25,15,6)
     2       ,BLAYER, RFORCE, SWIRL , TOTLEN, JLAYER, JFORCE
C
```

```
C      DENSITY (KG M**-3), IDEAL GAS AT 1 ATM.
C        (SUMASS IS GMOLES OF GAS PER KG OF GAS)
C
       DENS(SUMASS,TEMPER) = 273./(SUMASS*0.0224*TEMPER)
C
C      INITIALIZE CONSTANT PARAMETERS
C
       PI = 3.14159
C
C      INPUT FROM DATA FILE
C
       READ(5,210)(INCASE(I),I=1,70)
 210   FORMAT(70A1)
C
       READ(5,220)TBOIL,TLIQ
 220   FORMAT(8X,F10.4,9X,F10.4)
C
       READ(5,230)CPLIQ,LHELIQ,HCOMLQ
 230   FORMAT(8X,F10.4,9X,E10.3/8X,E10.3)
C
       READ(5,240)RHOLIQ, XNOZ
 240   FORMAT(8X,F10.4,9X,F10.4)
C
       READ(5,250)YNOZ, ZNOZ
 250   FORMAT(8X,F10.4,9X,F10.4)
C
       READ(5,260)NOZDIA, AFMRAT
 260   FORMAT(8X,E10.3,9X,F10.4)
C
       READ(5,270)ZSAFE,DSAFE
 270   FORMAT(8X,F10.4,9X,F10.4)
C
       READ(5,280)TSAFE,ESAFE
 280   FORMAT(8X,F10.4,9X,F10.4)
C
       READ(5,290)TOL1,NRAMP
 290   FORMAT(8X,F10.4,9X,I10)
C
       READ(5,300)MAXSTP,NDROP
 300   FORMAT(8X,I10,9X,I10)
C
       READ(5,310)NPRT1,NPRT2
       READ(5,310)NPRT3
 310   FORMAT(8X,I10,9X,I10)
C
       READ(5,320)INJOUT(1),INJOUT(2)
       READ(5,320)INJOUT(3),INJOUT(4)
       READ(5,320)INJOUT(5),INJOUT(6)
C
       READ(5,320)INPTYP(1),INPTYP(2)
       READ(5,320)INPTYP(3),INPTYP(4)
       READ(5,320)INPTYP(5),INPTYP(6)
 320   FORMAT(8X,I10,9X,I10)
C
       READ(5,330) TWDUM,TGDUM
```

```
      READ(5,330) UDUM,VDUM
      READ(5,330) SWIRL,TOTLEN
330   FORMAT(8X,F10.4,9X,F10.4)
C
      READ(5,340) JLAYER, JFORCE
340   FORMAT(8X,I10,9X,I10)
C
      READ(5,341) TIMAX
341   FORMAT(8X,I10)
C
C     COORDINATES OF ZONE BOUNDARIES
C
      XBDY(1) = 0.
      DO 600 I = 1,IX
        XBDY(I+1) = XBDY(I) + XL(I)
600   CONTINUE
C
      YBDY(1) = 0.
      DO 620 J = 1, IY
        YBDY(J+1) = YBDY(J) + R(J)
620   CONTINUE
C
      ZBDY(1) = 0.
      DO 640 K = 1, IZ
        ZBDY(K+1) = ZBDY(K) + DTHETA(K)
640   CONTINUE
C
C     CHECK TO SEE IF ANGULAR SECTORS ADD UP TO 360 DEGREES
C
      CYL = .TRUE.
      DUM1 = 360. - ABS(ZBDY(IZPLUS) - ZBDY(1))
      IF(DUM1.GT.+1.E-8) CYL = .FALSE.
      IF(DUM1.LT.-1.E-8) WRITE(6,650) DUM1
650   FORMAT(1X,'***ICSSET WARNING: SUM OF ANGULAR SECTORS IS'
     1          ,F5.1,' DEGREES OVER 360')
C
C     FIND LIMITS OF FORCED/FREE VORTEX AND BOUNDARY LAYER
C
      IF(JFORCE.GE.1) GOTO 670
        WRITE(6,680) JFORCE
680     FORMAT(1X,'ICSSET CORRECTION: JFORCE VALUE OF ',I3
     1            ,' WOULD CAUSE CENTERLINE ERROR.'
     2         ,/,4X,'CORRECTION: SET JFORCE = 1')
        JFORCE = 1
670   CONTINUE
      RFORCE = YBDY(JFORCE + 1)
      BLAYER = YBDY(IYPLUS) - YBDY(IYPLUS-JLAYER)
C
C     AREAS AND VELOCITIES AT ZONE BOUNDARIES (FROM MASS FLOWS)
C
C     CHECK FOR FLOW ACROSS CENTERLINE
C
      L = 0
      DO 770 K=1,IZ
      DO 770 I=1,IX
```

```
        IF(VBDY1(I,1,K).GT.1.E-6)L=1
770   CONTINUE
      IF(L.EQ.1) WRITE(6,780)
780   FORMAT(1X,'***ICSSET WARNING: FLOW ACROSS CENTERLINE NONZERO')
C
C     CONSTANTS FOR TANGENTIAL AND ROTATIONAL GAS VELOCITY
C
C
C     WALL TEMPERATURES
C
      IF(INPTYP(1).EQ.1)GOTO 910
        DO 920 J=1,IY
        DO 920 I=1,IX
          TWALL(I,J,K) = TEMP(I,J,K)
920     CONTINUE
910   CONTINUE
C
C     DUMMY INPUT OPTIONS
C
      IF(INPTYP(1).EQ.0)GOTO 1100
        DO 1110 K=1,IZ
        DO 1110 J=1,IY
        DO 1110 I=1,IX
          TWALL(I,J,K) = TWDUM
1110    CONTINUE
1100  CONTINUE
C
      IF(INPTYP(2).EQ.0)GOTO 1150
        DO 1160 K=1,IZ
        DO 1160 J=1,IY
        DO 1160 I=1,IX
          TEMP(I,J,K) = TGDUM
1160    CONTINUE
1150  CONTINUE
C
      IF(INPTYP(3).EQ.0)GOTO 1200
        DO 1210 K=1,IZ
        DO 1210 J=1,IY
        DO 1210 I=1,IXPLUS
          UBDY1(I,J,K) = UDUM
1210    CONTINUE
1200  CONTINUE
C
      IF(INPTYP(4).EQ.0)GOTO 1250
        DO 1260 K=1,IZ
        DO 1260 J=1,IYPLUS
        DO 1260 I=1,IX
          VBDY1(I,J,K) = VDUM
1260    CONTINUE
1250  CONTINUE
C
C     DUMMY SWIRL CALCULATION:
C
      IF(INPTYP(5).EQ.0)GOTO 1300
        DO 1320 K=1,IZPLUS
      DO 1320 J=1,IY
      DO 1320 I=1,IX
        DUM2 = ( XBDY(I) + XBDY(I+1) ) * 0.5
        DUM1 = (TOTLEN - DUM2) / (TOTLEN - XBDY(1))
        CFREE(I,J,K) = 4. * SWIRL * UBDY1(1,1,1) * DUM1 * RFORCE
        CFORCE(I,J,K)= 4. * SWIRL * UBDY1(1,1,1) * DUM1 / RFORCE
1320    CONTINUE
1300  CONTINUE
C
C     CALCULATION OF TANGENTIAL AND ROTATIONAL GAS VELOCITIES
C
      IF(INPTYP(5).EQ.1) GO TO 1401
        I1 = IY - JLAYER
        DO 1400 K=1,IZPLUS
        DO 1400 J=1,IY
        DO 1400 I=1,IX
          DUM1 = (YBDY(J+1) + YBDY(J)) * 0.5
          DUM2 = 1.
          IF(J.GT.I1) DUM2 = ( R(IY) - DUM1 ) / BLAYER
          IF(J.LE.JFORCE) GOTO 1410
          CFREE(I,J,K) = WBDY1(I,J,K) * DUM1 / DUM2
            ROTBDY(I,J,K) = WBDY1(I,J,K) / DUM1
1410      CONTINUE
          IF(J.GT.JFORCE) GOTO 1450
          CFORCE(I,J,K) = WBDY1(I,J,K) / DUM1 / DUM2
            ROTBDY(I,J,K) = WBDY1(I,J,K)   / DUM1
1450        CONTINUE
1400      CONTINUE
1401      CONTINUE
C
C     OPTIONAL OUTPUT
C
      IF(INJOUT(2).EQ.1) CALL ICPSET
C
      RETURN
      END
C ------------------------------------------------------------------
      SUBROUTINE ICSGAS
C
C     Modified from GPROP by Mark Sheldon for EER, 5/1/85
C
C     PURPOSE:
C       "ICSGAS" stands for:
C       "Incineration Cylindrical 3-d model,
C         GAS properties"
C
C     AVAILABLE CHEMICAL SPECIES:
C     No.  Formula  Name
C       1  O2       Diatomic Oxygen
C       2  N2       Diatomic Nitrogen
C       3  CO2      Carbon Dioxide
C       4  H2O      Water Vapor
C
C     Primary Reference:
C          Reid, Prausnitz and Sherwood  (1977)
C
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C          The Properties of Gases and Liquids, 3rd ed.
C
C     LOCAL VARIABLES
C
      REAL*4 CP(4)        , VISC(4)   , COND(4)
     1       ,MASSFR(4)   , MOLEFR(4), MOLWT(4)
     2       ,SIGMA(4)    , EPS(4)    , DELTA(4)
     3       ,TCRIT(4)    , KALPH(4)  , KCIR(4)
     4       ,VAFUN(4,4), VWGT(4)     , KWGT(4)
     5       ,VFUDGE(4)   , CFUDGE(4), KFUDGE(4)
     6       ,DUM1        , DUM2      , DUM3       , DUM4     , DUM5
     7       ,DUM6        , DUM7      , DUM8       , DUM9
     8       ,TDUM1       , TDUM2
      INTEGER  IPOLAR(4), TIMAX
      LOGICAL WARN1,WARN2
      REAL         MDOTIN
      LOGICAL*1    COMPND(40,20), CASE(60), INCASE
C
      COMMON/DIMCB/
     1       IX     , IY     , IZ     , IXPLUS, IYPLUS, IZPLUS
C
      COMMON/PRTCB/
     1       CASE   , INCASE(80)      , INJOUT(10), INPTYP(10)
     2       ,NPRT1 , NPRT2 , NPRT3
C
      COMMON/INPUT/
     3            V(25,15,5),   TEMP(25,15,5), MDOTIN
     4       ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC   , NPART
     5       ,II    , JI    , KI    , NCMPND, COMPND
C
      COMMON/GASCB/
     1       CPGAS(25,15,5) , DVISCG(25,15,5), TCONDG(25,15,5)
     2       ,FO2   , FN2   , FCO2   , FH2O
C
C     MOLECULAR PARAMETERS
C
C     NUMBER OF GAS SPECIES
      NGSPEC = 4
C
C     MOLECULAR WEIGHTS (G/GMOLE)
      DATA MOLWT /32.00   , 28.02   , 44.01   , 18.02   /
C
C     LENNARD-JONES (AND STOCKMEYER) PARAMETERS
C       (SIGMA IN ANGSTROMS, EPS IN KELVIN)
      DATA SIGMA /3.433   , 3.681   , 3.996   , 2.52    /
      DATA EPS   /113.    , 91.5    , 190.    , 775.    /
      DATA DELTA /0.0     , 0.0     , 0.0     , 1.0     /
C
C     CRITICAL TEMPERATURES (KELVIN)
      DATA TCRIT /154.8   , 126.2   , 304.2   , 647.3   /
C
C     PARAMETERS FOR POLAR VERSION OF THERMAL CONDUCTIVITY
C       (IPOLAR IS FLAG: =0 IF NONPOLAR, =1 IF POLAR)
C       (ALPHA AND CIR HAVE UNITS OF CAL/GMOLE/KELVIN)
      DATA IPOLAR/       0,         0,         0,         1/
      DATA KALPH / 0.0    , 0.0     , 0.0     , 0.90    /
      DATA KCIR  / 0.0    , 0.0     , 0.0     , 0.0     /
C
C     FUDGE FACTORS ARE RATIOS OF EXPERIMENTAL TO CALCULATED VALUES
C       AT REFERENCE TEMPERATURE (1300 K UNLESS OTHERWISE NOTED)
C
CNOTE: BEGIN BY USING FUDGE FACTORS SET TO 1.0
C
      DATA VFUDGE/ 1.0    , 1.0     , 1.0     , 1.0     /
      DATA KFUDGE/ 1.0    , 1.0     , 1.0     , 1.0     /
      DATA CFUDGE/ 1.0    , 1.0     , 1.0     , 1.0     /
C
C     INITIALIZE DEBUG OUTPUT LOGIC
C
      WARN1 = .FALSE.
      WARN2 = .FALSE.
C
C     TEMPERATURE-INDEPENDENT CALCULATIONS
C
C     MASS FRACTIONS
C
      MASSFR(1) = FO2
      MASSFR(2) = FN2
      MASSFR(3) = FCO2
      MASSFR(4) = FH2O
C
C     CHECK MASSFR NORMALIZATION
C
      DUM1 = -1.
      DO 210 L = 1,NGSPEC
        DUM1 = MASSFR(L) + DUM1
210     CONTINUE
      IF(DUM1.LT.-1.E-6) WRITE(6,220) DUM1
220   FORMAT(1X,'***ICSGAS WARNING: SUM OF MASS FRACTIONS IS '
     1          ,E10.3,' BELOW 1')
      IF(DUM1.GT.+1.E-6) WRITE(6,230) DUM1
230   FORMAT(1X,'***ICSGAS WARNING: SUM OF MASS FRACTIONS IS '
     1          ,E10.3,' ABOVE 1')
C
C     MOLE FRACTIONS
C
      DUM1 = 0.
      DO 310 L = 1, NGSPEC
        DUM1 = DUM1 + MASSFR(L)/MOLWT(L)
310   CONTINUE
      DO 320 L = 1, NGSPEC
        MOLEFR(L) = ( MASSFR(L)/MOLWT(L) ) / DUM1
320   CONTINUE
C
C     TEMPERATURE INDEPENDENT WEIGHTING FUNCTION (A) FOR MIX VISCOSITY
C
      DO 330 M = 1, NGSPEC
      DO 330 L = 1, NGSPEC
        DUM1 = MOLWT(L) / MOLWT(M)
        DUM2 = ( 4./ (1. + 1./DUM1) / (1. + DUM1) )**0.25
        DUM3 = DUM2 * (DUM1**(-0.5))
        DUM4 = DUM1 - (DUM1**(0.45))
        DUM5 = 2. * (1. + DUM1)
        DUM6 = (1. + (DUM1**(0.45)) ) * (DUM2**(-0.5))
        DUM7 = 1. + DUM2
        VAFUN(L,M) = DUM3 * (1. + DUM4/ (DUM5 + DUM6/DUM7) )
330   CONTINUE
C
C     LOOP THROUGH ALL ZONES I,J
C
      DO 1000 K = 1, IZ
      DO 1000 J = 1, IY
      DO 1000 I = 1, IX
C
C     LOOP FOR PURE COMPONENT PROPERTIES
C
      DO 2000 L = 1, NGSPEC
C
C     PURE COMPONENT HEAT CAPACITY
C
      TDUM1 = TEMP(I,J,K)*1.8
C
      IF(WARN1) GOTO 430
C
      IF(TDUM1.LT.540.) WRITE(6,410) TDUM1
410   FORMAT(1X,'***ICSGAS WARNING: GAS TEMP=',F8.1,'FARENHEIT, '
     1      ,/,4X,'TOO LOW  FOR EMPIRICAL CP EQNS. IN ICSGAS')
C
      IF(TDUM1.GT.5000.)WRITE(6,420) TDUM1
420   FORMAT(1X,'***ICSGAS WARNING: GAS TEMP=',F8.1,'FARENHEIT, '
     2      ,/,4X,'TOO HIGH FOR EMPIRICAL CP EQNS. IN ICSGAS')
C
      WARN1 = .TRUE.
430   CONTINUE
C
      IF(L.EQ.1) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * ( 11.515 - 172.*( TDUM1**(-0.5) ) + 1530./TDUM1 )
C
      IF(L.EQ.2) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * (  9.47  - 3.47E3 / TDUM1          + 1.16E6/TDUM1/TDUM1 )
C
      IF(L.EQ.3) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * ( 16.2   - 6.53E3 / TDUM1          + 1.41E6/TDUM1/TDUM1 )
C
      IF(L.EQ.4) CP(L) = ( 4186.5 * CFUDGE(L) / MOLWT(L) )
     1     * ( 19.86  - 597.*( TDUM1**(-0.5) ) + 7500./TDUM1 )
C
C     PURE COMPONENT VISCOSITY
C       (DUM1 IS THE INTEGRAL 'OMEGA' BASED ON STOCKMEYER POTENTIAL)
C
      TDUM1 = TEMP(I,J,K)/EPS(L)
C
      IF(WARN2) GOTO 460
C
      IF(TDUM1.LT.0.3) WRITE(6,440) TDUM1, L, I, J, K
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```
440   FORMAT(1X,'***ICSGAS WARNING: NONDIMEN TEMP = ',F6.2,/,4X
     1      ,'FOR SPECIES L=',I3,' AT ZONE I=',I3,', J=',I3,', K=',I3
     2      ,/,4X,'TOO LOW FOR ACCURATE VISCOSITY PREDICTION')
C
      IF(TDUM1.GT.100.) WRITE(6,450) TDUM1, L, I, J, K
450   FORMAT(1X,'***ICSGAS WARNING: NONDIMEN TEMP = ',F6.2,/,4X
     1      ,'FOR SPECIES L=',I3,' AT ZONE I=',I3,', J=',I3,', K=',I3
     2      ,/,4X,'TOO HIGH FOR ACCURATE VISCOSITY PREDICTION')
C
      WARN2 = .TRUE.
460   CONTINUE
C
      DUM1  =  1.16145 / (TDUM1**0.14874)
     1        + 0.52487 * EXP(-0.77320*TDUM1)
     2        + 2.16178 * EXP(-2.43787*TDUM1)
     3        + 0.2 * DELTA(L) * DELTA(L) / TDUM1
C
      VISC(L) = (26.69E-7 * SQRT( MOLWT(L)*TEMP(I,J,K) )
     1          / SIGMA(L) / SIGMA(L) / DUM1)
     2          * VFUDGE(L)
C
C     PURE COMPONENT THERMAL CONDUCTIVITY
C       (EQUATION HAS 2 FORMS, FOR NONPOLAR AND POLAR SPECIES)
C
      TDUM2 = TEMP(I,J,K)/TCRIT(L)
C
      IF(IPOLAR(L).EQ.0) COND(L) = (4.184E3 * VISC(L) / MOLWT(L))
     1     * (  3.107E-4 * CP(L) * MOLWT(L)
     2          - (0.70 / TDUM2) + 0.9168 )
     3     * KFUDGE(L)
C
      IF(IPOLAR(L).EQ.1) COND(L) = (4.184E3 * VISC(L) / MOLWT(L))
     1     * (  3.107E-4 * CP(L) * MOLWT(L)
     2          - (0.69 / TDUM2) + 1.077
     3          - (3. * KALPH(L)) - (0.3 * KCIR(L))  )
     4     * KFUDGE(L)
C
2000  CONTINUE
C
C     LOOP FOR MIXTURE WEIGHTING FUNCTIONS
C
      DO 3000 L = 1, NGSPEC
      VWGT(L) = 0.
      KWGT(L) = 0.
      DO 3000 M = 1, NGSPEC
C
C     VISCOSITY WEIGHTING FUNCTION
C
      DUM2 = 1.0
      IF((DELTA(L).GE.0.1).OR.(DELTA(M).GE.0.1))
     1 DUM2 = ( 1. +
     2            SQRT( (TEMP(I,J,K)/EPS(L)) * (TEMP(I,J,K)/EPS(M)) )
     3               + DELTA(L) * DELTA(M) * 0.25 )
     4      /SQRT( 1. + TEMP(I,J,K)/EPS(L) + DELTA(L)*DELTA(L)*0.25 )
     5      /SQRT( 1. + TEMP(I,J,K)/EPS(M) + DELTA(M)*DELTA(M)*0.25 )
```

```
C
      DUM3 = DUM2 * VAFUN(L,M) * SQRT( VISC(L)/VISC(M) )
C
      VWGT(L) = VWGT(L) + DUM3 * MOLEFR(M)
C
C     THERMAL CONDUCTIVITY WEIGHTING FUNCTION
C
      DUM4 = ( 1. + SQRT( VISC(L)/VISC(M) )
     1             *( MOLWT(M)/MOLWT(L) )**0.25 )**2.
     2      / SQRT( 8. * (1. + MOLWT(L)/MOLWT(M) ) )
C
      KWGT(L) = KWGT(L) + DUM4 * MOLEFR(M)
C
3000  CONTINUE
C
C     MIXTURE PROPERTIES
C
      CPGAS(I,J,K)  = 0.0
      DVISCG(I,J,K) = 0.0
      TCONDG(I,J,K) = 0.0
C
      DO 4000 L = 1, NGSPEC
        CPGAS(I,J,K)  = CPGAS(I,J,K)  + CP(L)   * MASSFR(L)
        DVISCG(I,J,K) = DVISCG(I,J,K) + VISC(L) * MOLEFR(L) / VWGT(L)
        TCONDG(I,J,K) = TCONDG(I,J,K) + COND(L) * MOLEFR(L) / KWGT(L)
4000  CONTINUE
C
1000  CONTINUE
C
C     OPTIONAL OUTPUT
C
      IF(INJOUT(1).EQ.1) CALL ICPGAS
C
      RETURN
      END
C -----------------------------------------------------------------------
      SUBROUTINE ICSDRP
C
C     Modified from DROP by Mark Sheldon for EER, 5/1/85
C
C     PURPOSE:
C       "ICSDRP" stands for:
C       "Incineration Cylindrical 3-d model,
C          Subroutine for DRoPlet history"
C
C     LOCAL VARIABLES
C
      REAL*4  NUSELT, LHELIQ, NOZDIA, KNOZ, MDOTIN, LOD
      INTEGER DSTMAX, DSTRIB, TIMAX
      LOGICAL*1   COMPND(40,20), CASE(60), INCASE
      LOGICAL     BOIL  , CNVRG , GETOUT, CYL, ENUF
C
      COMMON/DIMCB/
     1       IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
```

```
      COMMON/LIQCB/
     1        TBOIL , TLIQ   , RHOLIQ, LHELIQ, CPLIQ, HCOMLQ
C
      COMMON/NOZCB/
     1        NOZDIA, AFMRAT, KNOZ   , XNOZ   , YNOZ   , ZNOZ
     2       ,UPCOMP, VPCOMP, WPCOMP, UNOZ
C
      COMMON/PARMCB/
     1        ZSAFE , DSAFE , TSAFE , ESAFE , TOL1
     2       ,NDROP , MAXSTP, NRAMP
C
      COMMON/PRTCB/
     1        CASE   , INCASE(80)     , INJOUT(10), INPTYP(10)
     2       ,NPRT1 , NPRT2 , NPRT3
C
      COMMON/PRINT/
     1        DSTRIB(50,20),DSTMAX,NXMAX,NYMAX,XMEAN,YMEAN,ZMEAN
     2        , XFINAL, YFINAL, NXGRID, NYGRID
C
      COMMON/MOVECB/
     1        DTIME , DTSAV , OLDDT , TIME   , PATH   , DIAM
     2       ,UGAS  , VGAS  , WGAS  , IINEW , JINEW , KINEW
     3       ,ICNT1 , ICNT2 , PRANDT, BOIL   , CNVRG , GETOUT
C
      COMMON/INPUT/
     3             V(25,15,5),   TEMP(25,15,5), MDOTIN
     4       ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC   , NPART
     5       ,II    , JI    , KI    , NCMPND, COMPND
C
      COMMON/BDYCB/
     1        XL(25)     , XBDY(26)   , UBDY(26,15,5), UBDY1(26,15,5)
     2       ,R(15)      , YBDY(16)   , VBDY(25,16,5), VBDY1(25,16,5)
     3       ,DTHETA(5) , ZBDY(6)    , WBDY(25,15,6), WBDY1(25,15,6)
     4       ,ROTBDY(25,15,6), TWALL(25,15,5) , CYL
C
      COMMON/SWRLCB/
     1        CFORCE(25,15,6), CFREE(25,15,6)
     2       ,BLAYER, RFORCE, SWIRL , TOTLEN, JLAYER, JFORCE
C
      COMMON/GASCB/
     1        CPGAS(25,15,5) , DVISCG(25,15,5), TCONDG(25,15,5)
     2       ,FO2   , FN2   , FCO2  , FH2O
C
      COMMON/DROPCB/
     1        XPOLD, YPOLD, ZPOLD, UPOLD, VPOLD, WPOLD, DRPVEL
     2        XPINIT, YPINIT, ZPINIT, UPINIT, VPINIT, WPINIT
     3       ,DINIT , RNDNUM, SPACIN, C, SPACE, IT, LOD, VINIT1
C
      COMMON/SAVE/
     1   SAVEII,SAVEJI,SAVEKI,SAVEX,SAVEY,SAVEZ,SAVEU,SAVEV,SAVEW
C
C     DENSITY (KG M**-3), IDEAL GAS AT 1 ATM
C           (SUMASS IS GMOLES PER KG OF GAS MIXTURE)
C
      DENS(SUMASS,TEMPER) = 273./(SUMASS*0.0224*TEMPER)
```

```
C
C     DROPLET INITIAL CONDITIONS
      IF (IT.EQ.1) CALL ICSSPR
C
133   XPOLD = XPINIT
      YPOLD = YPINIT
      ZPOLD = ZPINIT
      UPOLD = UPINIT
      VPOLD = VPINIT
      WPOLD = WPINIT
      II = SAVEII
      JI = SAVEJI
      KI = SAVEKI
C
C     INITIALIZATIONS
C
      BOIL   = .FALSE.
      IF(TLIQ.GE.TBOIL) BOIL = .TRUE.
      IF(TLIQ.GT.TBOIL) WRITE(6,50)
50    FORMAT(1X,'SUPERHEATED DROPLET')
C
      CNVRG  = .FALSE.
      GETOUT = .FALSE.
      ENUF   = .FALSE.
C
      IINEW  = II
      JINEW  = JI
      KINEW  = KI
C
      DIAM   = DINIT
C
      TIME   = 0.0
      DTIME  = 1.0E-5
C
      UGAS = 0
      VGAS = 0.
      PI     = 3.14159
C
C     INITIALIZE GAS VELOCITY
C
      UGAS =  UBDY(II,JI,KI)
     1        + (UBDY(II+1,JI,KI) - UBDY(II,JI,KI))
     2          *(XPOLD - XBDY(II)) / (XBDY(II+1) - XBDY(II))
C
      VGAS =  VBDY(II,JI,KI)
     1        + (VBDY(II,JI+1,KI) - VBDY(II,JI,KI))
     2          *(YPOLD - YBDY(JI)) / (YBDY(JI+1) - YBDY(JI))
C
      I1 = IY - JLAYER
      DUM2 = 1.
      IF(JI.GT.I1) DUM2 = ( R(IY) - YPOLD ) / BLAYER
      IF(JI.LE.JFORCE) GOTO 200
        WGAS = CFREE(II,JI,KI) * DUM2 / YPOLD
200   CONTINUE
      IF(JI.GT.JFORCE) GOTO 210
```

```
        WGAS = CFORCE(II,JI,KI) * DUM2 * YPOLD
210   CONTINUE
      VINIT=((UPOLD-UGAS)**2+(VPOLD-VGAS)**2+(WPOLD-WGAS)**2)**0.5
      VINIT1=( UPOLD**2 + VPOLD**2 + WPOLD**2 )**0.5
C
C     ZONE CALCULATIONS
C          (ARBITRARY SAFETY LIMIT SET ON NUMBER OF ZONE PASSES)
C
      DO 1000 ICNT1 = 1,MAXSTP
C
C     CONSTANTS FOR TIMESTEP CALCULATION
C       NOTE CON1,CON2,CON3 USE DINIT, NOT DIAM
C       CORRECTION FACTOR OF (DIAM/DINIT)**2 IS APPLIED IN ICSMOV
C       TO ALLOW FOR TIMESTEP CHANGE IN DROPLET DIAMETER
C
      RENOLD = DIAM*DENS(SUMASS,TEMP(II,JI,KI))/DVISCG(II,JI,KI)
     1     *( (UPOLD-UGAS)**2 + (VPOLD-VGAS)**2 + (WPOLD-WGAS)**2 )**0.5
C
C        TRANSFER NUMBER
C
      TRANSNO = CPGAS(II,JI,KI) * (TEMP(II,JI,KI)-TLIQ)/LHELIQ
     1          + HCOMLQ * FO2 / AFMRAT / LHELIQ
C
C       ETAE ACCOUNTS FOR EFFECT OF EVAPORATION ON DRAG
C
      ETAE=1
      IF (BOIL) ETAE = 1./(1 + TRANSNO)
C
C       SET DRAG COEFFICIENT AND ADJUST FOR CLOSELY SPACED DROPLETS
C
      IF(RENOLD.LE.80) CD1 = 27. * RENOLD**(-0.84)
      IF(RENOLD.GT.80.AND.RENOLD.LT.1.E4)
     1       CD1 = 0.271 * RENOLD**(0.217)
      IF(RENOLD.GE.1.E4) CD1 = 2.
C
      VDT = (UPOLD**2 + VPOLD**2 + WPOLD**2) **0.5
      VMAG=((UPOLD-UGAS)**2+(VPOLD-VGAS)**2+(WPOLD-WGAS)**2)**0.5
      IF(.NOT.BOIL) SPACE = VDT * SPACIN / VINIT1
      IF(SPACE.LT.DIAM) SPACE = DIAM
      CD2= 0.755/RENOLD + 34.8 * RENOLD**(-1.009) * (SPACE/DIAM-1)
      CD = (CD1 **(-0.7072) + CD2 **(-0.7072)) ** (-1/0.7072)
      CD = CD * ETAE
      CDRE = CD * RENOLD
C
C       DETERMINE TIMESTEPS
C
      CON1 = -1.
      IF(CDRE.GT.1.E-10)
     1      CON1 = 1./( 18. *DVISCG(II,JI,KI) /RHOLIQ /DINIT /DINIT
     2      * CDRE / 24.)
C
      PRANDT = CPGAS(II,JI,KI) * DVISCG(II,JI,KI) / TCONDG(II,JI,KI)
      NUSELT = 2. + 0.6 * (RENOLD**0.5) * (PRANDT**(1./3.))
      CON2 = RHOLIQ * DINIT * DINIT * CPLIQ
     1      / 6. / NUSELT / TCONDG(II,JI,KI)
```

```
C
      CBOIL = -1.
      IF(TEMP(II,JI,KI).GE.TLIQ) CBOIL =
     1   8. * TCONDG(II,JI,KI) / RHOLIQ / CPGAS(II,JI,KI)
     2   *ALOG(1. + TRANSNO)
      CON3 = DINIT*DINIT/CBOIL/(1. + 0.23*(RENOLD**0.5))
C
C     TIMESTEP SIZE
C
      OLDDT = DTIME
C
      TIME1 = 1.E20
      IF(UPOLD.GT.+1.E-7) TIME1 = (XBDY(II+1) - XPOLD) /UPOLD *ZSAFE
      IF(UPOLD.LT.-1.E-7) TIME1 = (XBDY(II)   - XPOLD) /UPOLD *ZSAFE
C
      TIME2 = 1.E20
      IF(VPOLD.GT.+1.E-7) TIME2 = (YBDY(JI+1) - YPOLD) /VPOLD *ZSAFE
      IF(VPOLD.LT.-1.E-7) TIME2 = (YBDY(JI)   - YPOLD) /VPOLD *ZSAFE
C
      TIME3 = 1.E20
      IF(WPOLD.GT.+1.E-7) TIME3 = ZSAFE * 2. * PI * YPOLD
     1                      *(ZBDY(KI+1) - ZPOLD) / 360. /WPOLD
      IF(WPOLD.LT.-1.E-7) TIME3 = ZSAFE * 2. * PI * YPOLD
     1                      *(ZBDY(KI)   - ZPOLD) / 360. /WPOLD
C
      TIME4 = 1.E20
      IF(CON1.GE.0.)  TIME4 = CON1*DSAFE
C
      TIME5 = 1.E20
      IF(.NOT.BOIL)   TIME5 = CON2*TSAFE
C
      TIME6 = 1.E20
      IF(CBOIL.GE.0.) TIME6 = CON3*ESAFE
C
      DUM1 = OLDDT
      IF(TIME1.GT.0.0)                     DUM1 = TIME1
      IF(TIME2.GT.0.0.AND.TIME2.LE.DUM1) DUM1 = TIME2
      IF(TIME3.GT.0.0.AND.TIME3.LE.DUM1) DUM1 = TIME3
      IF(TIME4.GT.0.0.AND.TIME4.LE.DUM1) DUM1 = TIME4
      IF(TIME5.GT.0.0.AND.TIME5.LE.DUM1) DUM1 = TIME5
      IF(TIME6.GT.0.0.AND.TIME6.LE.DUM1) DUM1 = TIME6
      IF(DUM1.LE.1.E+21) DTIME = DUM1
      DTSAV = DTIME
C
C     TIMESTEPS ACROSS ZONE
C
      DO 2000 ICNT2 = 1,MAXSTP
        CALL ICSMOV
        IF(GETOUT) GOTO 600
C
C     CHECK FOR ZONE BOUNDARY
C       IF STILL IN ZONE, CONTINUE IN 'DO 2000' LOOP FOR NEXT TIMESTEP
C       IF ZONE BOUNDARY REACHED, GET OUT OF 'DO 2000' LOOP
C
      IF (IINEW.NE.II) GOTO 600
      IF (JINEW.NE.JI) GOTO 600
      IF (KINEW.NE.KI) GOTO 600
2000  CONTINUE
C
C     IF NOT OUT OF ZONE IN REASONABLE TIME, DROPLET MAY BE OUT OF STEAM
C
      IF(INJOUT(3).EQ.1) WRITE(6,610)MAXSTP
610   FORMAT(1X,/,1X,'STILL IN ZONE AFTER ',I7,' STEPS.')
      RETURN
C
C     END-OF-ZONE CALCULATIONS
C
600   CONTINUE
C
C     CHECK WHETHER ZONE BOUNDARY IS A SOLID WALL
C
      IF(IINEW.LT.1)                ENUF = .TRUE.
      IF(IINEW.GT.IX)               ENUF = .TRUE.
      IF(.NOT.CYL.AND.JINEW.LT.1)   ENUF = .TRUE.
      IF(JINEW.GT.IY)               ENUF = .TRUE.
      IF(.NOT.CYL.AND.KINEW.LT.1)   ENUF = .TRUE.
      IF(.NOT.CYL.AND.KINEW.GT.IZ)  ENUF = .TRUE.
      IF(.NOT.ENUF) GOTO 700
C
      IF(BOIL.OR.TWALL(II,JI,KI).GT.TBOIL) GOTO 620
      IF(INJOUT(3).EQ.1) WRITE(6,630)
630   FORMAT(1X,'ICSDRP: DROP CONDENSED ON COLD SURFACE, WILL NOT BOIL')
      RETURN
C
620   CONTINUE
      IF(INJOUT(3).EQ.1) WRITE(6,640)
640   FORMAT(1X,'ICSDRP: DROP ON WALL, WILL EVAPORATE IN THIS ZONE')
      RETURN
C
C     CHECK FOR EVAPORATION IN PAST ZONE
C
700   CONTINUE
      DMASS =  (DIAM / DINIT)**3.
      IF(DMASS.GT.1.0E-18) GOTO 710
        DUM1 = DIAM * 1.E6
      IF(INJOUT(3).EQ.1) WRITE(6,720)II,JI,KI,ICNT2,TIME,XPOLD,
     1 YPOLD,ZPOLD,UPOLD,VPOLD,WPOLD,TLIQ,DUM1,UGAS,VGAS,WGAS
720     FORMAT(' ',3I3,I5,E10.3,2F6.3,F6.1,3F7.2,F7.1,F8.2,3F7.2)
        RETURN
C
C     IF NOT EVAPORATED, ENTER NEW ZONE
C
710   CONTINUE
C
C       (NEW AXIAL ZONE)
C
      II = IINEW
C
C       (NEW RADIAL ZONE)
C
```

```
      IF(JINEW.NE.0) GOTO 800
C        (AT CENTERLINE, RADIAL VEL CHANGES SIGN, TANGENT VEL IS ZERO
C         AND ENTERS NEW SECTOR 180 DEG AWAY)
        VPOLD = -VPOLD
        WPOLD = 0.
        JINEW = 1
        ZPOLD = ZPOLD + 180.
        IF(ZPOLD.GT.360.) ZPOLD = ZPOLD - 360.
C
C       WHEN CENTERLINE CROSSED, MUST FIGURE NEW TANGENTIAL ZONE
C
        KINEW = 1
        DO 810 K = 2, IZPLUS
          IF(ZPOLD.LT.ZBDY(KI)) GOTO 820
          KINEW = KINEW+1
810     CONTINUE
820     CONTINUE
        IF(KINEW.GT.IZ) KINEW = IZ
C
800   CONTINUE
      JI = JINEW
C
C       (NEW TANGENTIAL ZONE)
C
      IF(KINEW.NE.IZPLUS) GOTO 801
        ZPOLD = 0.
        KINEW = 1
801   CONTINUE
      IF(KINEW.NE.0) GOTO 802
        ZPOLD = 360.
        KINEW = IZ
802   CONTINUE
      KI = KINEW
C
C     IF TEMP OF NEW ZONE IS < TBOIL, RECALCULATE DROP TEMP
C
      IF(TEMP(II,JI,KI).LT.TBOIL) BOIL = .FALSE.
C
1000  CONTINUE
C
C     IF ZONE LOOP COMPLETED WITHOUT EVAPORATION, SEND WARNING MESSAGE
C
      IF(INJOUT(3).EQ.1) WRITE(6,900) MAXSTP
900   FORMAT(1X,'ICSDRP: DROPLET NOT EVAPORATED AFTER '
     1         ,I8,' ZONES VISITED')
      RETURN
      END
C -----------------------------------------------------------------
      SUBROUTINE ICSSPR
C
C     Modified from SPRAY by Mark Sheldon, 5/1/85
C
C     PURPOSE:
C       "ICSSPR" stands for:
C       "Incineration Cylindrical 3-d model,
C         Subroutine for SPRay characteristics"
C
      REAL    LOD, MDOTIN, LHELIQ, NOZDIA, KNOZ
      INTEGER      TIMAX, DSTRIB
      LOGICAL*1    COMPND(40,20), CASE(60), INCASE
      LOGICAL      CYL
C
      COMMON/DIMCB/
     1        IX     , IY     , IZ     , IXPLUS, IYPLUS, IZPLUS
C
      COMMON/LIQCB/
     1        TBOIL  , TLIQ   , RHOLIQ, LHELIQ, CPLIQ, HCOMLQ
C
      COMMON/NOZCB/
     1        NOZDIA, AFMRAT, KNOZ   , XNOZ   , YNOZ   , ZNOZ
     2       ,UPCOMP, VPCOMP, WPCOMP, UNOZ
C
      COMMON/PARMCB/
     1        ZSAFE  , DSAFE  , TSAFE  , ESAFE  , TOL1
     2       ,NDROP  , MAXSTP, NRAMP
C
      COMMON/PRTCB/
     1        CASE   , INCASE(80)      , INJOUT(10), INPTYP(10)
     2       ,NPRT1  , NPRT2  , NPRT3
C
      COMMON/INPUT/
     3             V(25,15,5),    TEMP(25,15,5), MDOTIN
     4       ,SUMASS, TIMAX  , TEMAX  , TEMIN  , TAUC   , NPART
     5       ,II     , JI     , KI     , NCMPND, COMPND
C
      COMMON/BDYCB/
     1        XL(25)     , XBDY(26)    , UBDY(26,15,5), UBDY1(26,15,5)
     2       ,R(15)      , YBDY(16)    , VBDY(25,16,5), VBDY1(25,16,5)
     3       ,DTHETA(5)  , ZBDY(6)     , WBDY(25,15,6), WBDY1(25,15,6)
     4       ,ROTBDY(25,15,6), TWALL(25,15,5) , CYL
C
      COMMON/GASCB/
     1        CPGAS(25,15,5) , DVISCG(25,15,5), TCONDG(25,15,5)
     2       ,FO2    , FN2    , FCO2   , FH2O
C
      COMMON/DROPCB/
     1        XPOLD, YPOLD, ZPOLD, UPOLD, VPOLD, WPOLD, DRPVEL
     2        XPINIT, YPINIT, ZPINIT, UPINIT, VPINIT, WPINIT
     2       ,DINIT , RNDNUM, SPACIN, C, SPACE, IT, LOD
C
      COMMON/SAVE/
     1   SAVEII,SAVEJI,SAVEKI,SAVEX,SAVEY,SAVEZ,SAVEU,SAVEV,SAVEW
C
C     INPUT FROM DATA FILE
C
      READ(5,100) DINIT
100   FORMAT(8X,E10.3)
C
      READ(5,110) DRPVEL
      READ(5,110) XPCOMP
      READ(5,110) YPCOMP
      READ(5,110) ZPCOMP
      READ(5,110) LOD
110   FORMAT(8X,F10.4)
C
C     DROPLET INITIAL POSITION (AT INJECTION LOCATION)
C
      XPOLD = XNOZ
      YPOLD = YNOZ
      ZPOLD = ZNOZ
      XPINIT= XPOLD
      YPINIT= YPOLD
      ZPINIT= ZPOLD
      SPACIN = LOD * DINIT
C
C     DROPLET INITIAL VELOCITY
C
      UPOLD = DRPVEL * XPCOMP
      VPOLD = DRPVEL * YPCOMP
      WPOLD = DRPVEL * ZPCOMP
      UPINIT= UPOLD
      VPINIT= VPOLD
      WPINIT= WPOLD
C
C     LOCATE INITIAL ZONE
C
      II = 1
      DO 200 I = 2, IXPLUS
        IF(XPOLD.LT.XBDY(I)) GOTO 210
        II = II + 1
200   CONTINUE
210   CONTINUE
      IF(II.GT.IX) II = IX
C
      JI = 1
      DO 300 J = 2, IYPLUS
        IF(YPOLD.LT.YBDY(J)) GOTO 310
        JI = JI + 1
300   CONTINUE
310   CONTINUE
      IF(JI.GT.IY) JI = IY
C
      KI = 1
      DO 400 K = 2, IZPLUS
        IF(ZPOLD.LT.ZBDY(K)) GOTO 410
        KI = KI + 1
400   CONTINUE
410   CONTINUE
      IF(KI.GT.IZ) KI = IZ
      SAVEII = II
      SAVEJI = JI
      SAVEKI = KI
C
C     CONCLUDE SPRAY INPUT/OUTPUT:
C
```

```
      IF(INJOUT(3).EQ.1) CALL ICPSPR
C
C     CHECKS ON VELOCITY COMPONENTS
C
      DUM1 = 1. - ( XPCOMP**2 + YPCOMP**2 + ZPCOMP**2 )
      IF(ABS(DUM1).GT.1.E-4) WRITE(6,120)DUM1
120   FORMAT(1X,'***ICSSPR WARNING:'
     1          ,' SQUARE OF DRPVEL COMPONENTS =',E10.3,'BELOW 1')
C
      IF(YPOLD.LT.0.0)WRITE(6,130)
130   FORMAT(1X,'***ICSSPR WARNING: STARTING AT NEGATIVE RADIUS')
C
      IF(YPOLD.LE.0.0.AND.YPCOMP.LT.0.0)WRITE(6,140)
140   FORMAT(1X,'***ICSSPR WARNING: HEADED TOWARD NEGATIVE RADII')
C
      IF(YPOLD.LE.0.0.AND.ABS(ZPCOMP).GT.1E-10)WRITE(6,150)
150   FORMAT(1X,'***ICSSPR WARNING: NONZERO TANG VEL AT CENTERLINE')
C
      RETURN
      END
C ---------------------------------------------------------------------
      SUBROUTINE ICSMOV
C
C     Modified from DRPMOV by Mark Sheldon for EER, 5/1/85
C
C     PURPOSE:
C       "ICSMOV" stands for:
C       "Incineration Cylindrical 3-d model,
C         Subroutine for droplet MOVement"
C
      REAL*4  NUSELT, MDOTIN, LHELIQ, LOD , NOZDIA, KNOZ
      INTEGER      TIMAX , DSTRIB
      LOGICAL*1    COMPND(40,20), CASE(60) , INCASE
      LOGICAL      BOIL  , CNVRG , GETOUT, PRTLIN, CYL
C
      COMMON/DIMCB/
     1        IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
      COMMON/LIQCB/
     1        TBOIL , TLIQ  , RHOLIQ, LHELIQ, CPLIQ, HCOMLQ
C
      COMMON/NOZCB/
     1        NOZDIA, AFMRAT, KNOZ  , XNOZ  , YNOZ  , ZNOZ
     2       ,UPCOMP, VPCOMP, WPCOMP, UNOZ
C
      COMMON/PARMCB/
     1        ZSAFE , DSAFE , TSAFE , ESAFE , TOL1
     2       ,NDROP , MAXSTP, NRAMP
C
      COMMON/PRTCB/
     1        CASE  , INCASE(80)     , INJOUT(10), INPTYP(10)
     2       ,NPRT1 , NPRT2 , NPRT3
C
      COMMON/MOVECB/
     1        DTIME , DTSAV , OLDDT , TIME  , PATH  , DIAM
     2      ,UGAS  , VGAS  , WGAS  , IINEW , JINEW , KINEW
     3      ,ICNT1 , ICNT2 , PRANDT, BOIL  , CNVRG , GETOUT
C
      COMMON/INPUT/
     3            V(25,15,5),   TEMP(25,15,5), MDOTIN
     4      ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC  , NPART
     5      ,II    , JI    , KI    , NCMPND, COMPND, JRAND
C
      COMMON/BDYCB/
     1       XL(25)    , XBDY(26)  , UBDY(26,15,5), UBDY1(26,15,5)
     2      ,R(15)     , YBDY(16)  , VBDY(25,16,5), VBDY1(25,16,5)
     3      ,DTHETA(5) , ZBDY(6)   , WBDY(25,15,6), WBDY1(25,15,6)
     4      ,ROTBDY(25,15,6), TWALL(25,15,5) , CYL
C
      COMMON/SWRLCB/
     1       CFORCE(25,15,6), CFREE(25,15,6)
     2      ,BLAYER, RFORCE, SWIRL , TOTLEN, JLAYER, JFORCE
C
      COMMON/GASCB/
     1       CPGAS(25,15,5) , DVISCG(25,15,5), TCONDG(25,15,5)
     2      ,FO2   , FN2   , FCO2  , FH2O
C
      COMMON/DROPCB/
     1       XPOLD, YPOLD, ZPOLD, UPOLD, VPOLD, WPOLD, DRPVEL
     2       XPINIT, YPINIT, ZPINIT, UPINIT, VPINIT, WPINIT
     3      ,DINIT , RNDNUM, SPACIN, C, SPACE, IT, LOD, VINIT1
C
C     CONSTANT DATA
C
      DATA PI/3.14159/
C
C     DENSITY (KG M**-3), IDEAL GAS AT 1 ATM
C          (SUMASS IS GMOLES PER KG OF GAS MIXTURE)
C
      DENS(SUMASS,TEMPER) = 273./(SUMASS*0.0224*TEMPER)
C
C     OUTPUT LOGIC
C
      PRTLIN = .FALSE.
      IF(ICNT2.LE.NPRT1)          PRTLIN = .TRUE.
      IF(MOD(ICNT2,NPRT2).EQ.0)   PRTLIN = .TRUE.
      IF(INJOUT(3).EQ.0)          PRTLIN = .FALSE.
C
      I1 = IX * IY * IZ
      IF(NPRT1.GT.I1) I1 = NPRT1
      IF(ICNT1.GT.I1)             PRTLIN = .FALSE.
C
C     ADJUST TIMESTEP FOR EARLY PART OF ZONE
C
      DTIME = DTSAV
      IF(ICNT2.LE.NRAMP.AND.ICNT1.EQ.1)
     1       DTIME = DTSAV*FLOAT(ICNT2)/FLOAT(NRAMP)
C
C     ADJUST TIMESTEP FOR EVAPORATION
C
```

```
      DTIME = DTIME * (DIAM/DINIT)**2
C
C     UPDATE DROP POSITION
C
      XPNEW = XPOLD + UPOLD*DTIME
      DUM1 = XBDY(II+1) + 1.0E-8
      IF(XPNEW.LT.DUM1) GOTO 300
        IINEW = II + 1
        DTIME = (XBDY(II+1) - XPOLD) /UPOLD
        XPNEW = XBDY(II+1)
  300 CONTINUE
      DUM2 = XBDY(II) - 1.0E-8
      IF(XPNEW.GT.DUM2) GOTO 310
        IINEW = II - 1
        DTIME = (XBDY(II) - XPOLD) /UPOLD
        XPNEW = XBDY(II)
  310 CONTINUE
C
      YPNEW = YPOLD + VPOLD*DTIME
      DUM3 = YBDY(JI+1) + 1.0E-8
      IF(YPNEW.LT.DUM3) GOTO 320
        JINEW = JI + 1
        DTIME = (YBDY(JI+1) - YPOLD) /VPOLD
        YPNEW = YBDY(JI+1)
  320 CONTINUE
      DUM4 = YBDY(JI) - 1.0E-8
      IF(YPNEW.GT.DUM4) GOTO 330
        JINEW = JI - 1
        DTIME = (YBDY(JI) - YPOLD) /VPOLD
        YPNEW = YBDY(JI)
  330 CONTINUE
C
      ZPNEW = ZPOLD
      IF(YPOLD.GT.1.E-10)
     1       ZPNEW = ZPOLD + WPOLD*DTIME /YPOLD * 180. /PI
      DUM5 = ZBDY(KI+1) + 1.0E-8
      IF(ZPNEW.LT.DUM5) GOTO 340
        KINEW = KI + 1
        DTIME = (ZBDY(KI+1)-ZPOLD)*PI/180. *YPOLD/WPOLD
        ZPNEW = ZBDY(KI+1)
  340 CONTINUE
      DUM6 = ZBDY(KI) - 1.0E-8
      IF(ZPNEW.GT.DUM6) GOTO 350
        KINEW = KI - 1
        DTIME = (ZBDY(KI)-ZPOLD)*PI/180. *YPOLD/WPOLD
        ZPNEW = ZBDY(KI)
  350 CONTINUE
C
C     CHECK FOR NEGATIVE OR HUGE TIMESTEPS NEAR BOUNDARY
C       (NEGATIVE TIMESTEP MEANS XPOLD WAS ACTUALLY IN NEW ZONE)
C       (HUGE TIMESTEP MEANS DROPLET VELOCITY VERY SMALL)
C
      IF(II.EQ.IINEW.AND.JI.EQ.JINEW.AND.KI.EQ.KINEW) GOTO 360
        IF(DTIME.GE.0.0) GOTO 370
          DTIME = OLDDT
```

```
            GETOUT = .TRUE.
            RETURN
370       CONTINUE
          IF(DTIME.GE.1.E22) DTIME = OLDDT
360     CONTINUE
C
C              UPDATE DROPLET VELOCITY AT NEW POSITION
C               (CDRE IS DRAG COEFF X REYNOLD NUMBER)
C
C          ALLOWANCE FOR GRAVITY
C
        GRAVX = -9.81
        GRAVY =  0.
        GRAVZ =  0.
        IF (INJOUT(5).EQ.1) GO TO 364
        GRAVX =  0.
        GRAVY = -9.81 * SIN (ZPOLD)
        GRAVZ = -9.81 * COS (ZPOLD)
C
        RENOLD = DIAM*DENS(SUMASS,TEMP(II,JI,KI))/DVISCG(II,JI,KI)
     1     *((UPOLD-UGAS)**2 + (VPOLD-VGAS)**2 + (WPOLD-WGAS)**2 )**0.5
C
        IF(RENOLD.LE.80) CD1 = 27. * RENOLD**(-0.84)
        IF(RENOLD.GT.80.AND.RENOLD.LT.1.E4)
     1        CD1 = 0.271 * RENOLD**(0.217)
        IF(RENOLD.GE.1.E4) CD1 = 2.
C
C ADJUST DRAG FOR CLOSELY SPACED DROPLETS
C
364     VMAG=((UPOLD-UGAS)**2+(VPOLD-VGAS)**2+(WPOLD-WGAS)**2)**0.5
        DRPVEL = (UPINIT**2 + VPINIT**2 + WPINIT**2) **0.5
        VDT = (UPOLD**2 + VPOLD**2 + WPOLD**2) **0.5
        IF(.NOT.BOIL)  SPACE = VDT * SPACIN / VINIT1
        IF(SPACE.LT.DIAM) SPACE = DIAM
        CD2= 0.755/RENOLD + 34.8 * RENOLD**(-1.009) * (SPACE/DIAM-1)
        CD = (CD1 **(-0.7072) + CD2 **(-0.7072)) ** (-1/0.7072)
        CDRE = CD * RENOLD
C
C            TRANSFER NUMBER
C
        TRANSNO = CPGAS(II,JI,KI) * (TEMP(II,JI,KI)-TLIQ)/LHELIQ
     1            + HCOMLQ * FO2 / AFMRAT / LHELIQ
C
C          ETAE ACCOUNTS FOR EFFECT OF EVAPORATION ON DRAG
C
        ETAE=1
        IF (BOIL) ETAE = 1./(1 + TRANSNO)
C
        CDPL = CD * ETAE
        CDPD = CD1 * ETAE
        UDIF = UPOLD - UGAS
        VDIF  = VPOLD - VGAS
        WDIF = WPOLD - WGAS
        VDX = VPOLD * SIN(ZPOLD*3.14159/180) + WPOLD * COS(ZPOLD * 3.14159
     1        /180)
```

```
      VDY = VPOLD * COS(ZPOLD*3.14159/180) - WPOLD * SIN(ZPOLD * 3.14159
     1          /180)
      VDZ = UPOLD
      VRX = VDIF * SIN(ZPOLD*3.14159/180) + WDIF *COS(ZPOLD*3.14159/180)
      VRY = VDIF * COS(ZPOLD*3.14159/180) - WDIF *SIN(ZPOLD*3.14159/180)
      VRZ = UDIF
C
      VRPL = (VRX * VDX + VRY * VDY + VRZ * VDZ) / VDT
C
      VRPLX = VRPL * VDX / VDT
      VRPLY = VRPL * VDY / VDT
      VRPLZ = VRPL * VDZ / VDT
C
      VRPDX = VRX - VRPLX
      VRPDY = VRY - VRPLY
      VRPDZ = VRZ - VRPLZ
C
      DUM1 = 0.75 * DENS(SUMASS,TEMP(II,JI,KI))/RHOLIQ/DIAM
C
      DRAGX = DUM1 * (CDPL * VRPLX**2 + CDPD * VRPDX**2)
      DRAGY = DUM1 * (CDPL * VRPLY**2 + CDPD * VRPDY**2)
      DRAGZ = DUM1 * (CDPL * VRPLZ**2 + CDPD * VRPDZ**2)
C
      DRAGR = DRAGX *SIN(ZPOLD*PI/180) + DRAGY*COS(ZPOLD*PI/180)
      DRAGTH= DRAGX *COS(ZPOLD*PI/180) - DRAGY*SIN(ZPOLD*PI/180)
      IF(UDIF.GE.0) DRAGZ = -DRAGZ
      IF(VDIF.GE.0) DRAGR = -DRAGR
      IF(WDIF.GE.0) DRAGTH= -DRAGTH
C
      UPNEW = UPOLD + DRAGZ * DTIME + GRAVX * DTIME
      DUM2  = 0.
      IF(YPOLD.GT.1.E-10) DUM2   WPOLD**2 /YPOLD * DTIME
      VPNEW = VPOLD + DRAGR * DTIME + DUM2 + GRAVY*DTIME
      DUM3  = 0.
      IF(YPOLD.GT.1.E-10) DUM3 = VPOLD * WPOLD / YPOLD *DTIME
      WPNEW = WPOLD + DRAGTH * DTIME - DUM3 + GRAVZ*DTIME
C
C
C     UPDATE GAS VELOCITY AT NEW POSITION
C
      UGAS = UBDY(II,JI,KI)
     1       + (UBDY(II+1,JI,KI) - UBDY(II,JI,KI))
     2         *(XPNEW - XBDY(II)) / (XBDY(II+1) - XBDY(II))
C
      VGAS = VBDY(II,JI,KI)
     1       + (VBDY(II,JI+1,KI) - VBDY(II,JI,KI))
     2         *(YPNEW - YBDY(JI)) / (YBDY(JI+1) - YBDY(JI))
C
      I1 = IY - JLAYER
      DUM2 = 1.
      IF(JI.GT.I1) DUM2 = ( R(IY) - YPNEW ) / BLAYER
      IF(JI.LE.JFORCE) GOTO 450
        DUM3 = CFREE(II,JI,KI)   * DUM2 / YPNEW
        DUM4 = CFREE(II,JI,KI+1) * DUM2 / YPNEW
450   CONTINUE
```

```
      IF(JI.GT.JFORCE) GOTO 460
        DUM3 = CFORCE(II,JI,KI)  * DUM2 * YPNEW
        DUM4 = CFORCE(II,JI,KI+1)* DUM2 * YPNEW
460   CONTINUE
      WGAS = DUM3 + (DUM4-DUM3)
     1                   * (ZPNEW - ZBDY(KI)) / (ZBDY(KI+1)-ZBDY(KI))
C
C     UPDATE DROPLET TEMPERATURE AND DIAMETER
C
C       ETAS ACCOUNTS FOR EFFECT OF DROPLET SPACING ON EVAPORATION
C
       ETAS = 1 - (DIAM/SPACE/2) + (DIAM/SPACE/2)**2
C
C     CASE WHERE DROP IS BOILING
C
      IF(.NOT.BOIL) GOTO 500
        CBOIL = 8. * TCONDG(II,JI,KI) / RHOLIQ / CPGAS(II,JI,KI)
     1    * ALOG (1 + TRANSNO)
        DUM2 = DIAM*DIAM - ETAS * CBOIL * (1. + 0.23 * RENOLD**0.5)
     1      * DTIME
        DUM3 = DUM2 /DINIT /DINIT
        IF(DUM3.GT.1.E-12) GOTO 510
          WRITE(6,570)
          XPOLD = XPNEW
          YPOLD = YPNEW
          ZPOLD = ZPNEW
          UPOLD = UPNEW
          VPOLD = VPNEW
          WPOLD = WPNEW
          TIME  = TIME + DTIME
          DIAM = 0.
          GETOUT = .TRUE.
          RETURN
510     CONTINUE
        DIAM = DUM2**0.5
        TLNEW = TLIQ
C
C     CASE WHERE DROP TEMPERATURE IS CHANGING
C
500   CONTINUE
      IF(BOIL) GOTO 550
        NUSELT = 2. + 0.6 * (RENOLD**0.5) * (PRANDT**(1./3.))
        DUM3   = 6. *NUSELT *TCONDG(II,JI,KI)
     1             /RHOLIQ /DIAM /DIAM /CPLIQ
        TLNEW  = TEMP(II,JI,KI)
     1            - (TEMP(II,JI,KI)-TLIQ) * EXP(-DUM3 * DTIME)
C
C     CASE WHERE DROP STARTS BOILING DURING STEP (STARTS TO SHRINK TOO)
C
      IF(TLNEW.LT.TBOIL) GOTO 550
        DUM4 = DTIME - (1./DUM3)
     1         *ALOG((TEMP(II,JI,KI)-TLIQ)/(TEMP(II,JI,KI)-TBOIL))
        CBOIL = 8. * TCONDG(II,JI,KI) / RHOLIQ / CPGAS(II,JI,KI)
     1    * ALOG(1 + TRANSNO)
        DUM2 = (DIAM*DIAM - ETAS * CBOIL * (1.+0.23*RENOLD**0.5) * DUM4)
      DUM3 = DUM2 /DINIT /DINIT
      IF(DUM3.GT.1.E-12) GOTO 560
        WRITE(6,570)
570     FORMAT(1X,'DROP ASSUMED EVAPORATED WHEN 1.E-6'
     1          ,' OF INITIAL DIAMETER')
        XPOLD = XPNEW
        YPOLD = YPNEW
        ZPOLD = ZPNEW
        UPOLD = UPNEW
        VPOLD = VPNEW
        WPOLD = WPNEW
        TIME  = TIME + DTIME
        DIAM = 0.
        GETOUT = .TRUE.
        RETURN
560   CONTINUE
      DIAM = DUM2**0.5
      TLNEW = TBOIL
      BOIL = .TRUE.
C
C     TEST FOR VELOCITY CONVERGENCE
C
550   CONTINUE
      DUM1 = ABS(UGAS-UPNEW)
      DUM2 = ABS(VGAS-VPNEW)
      DUM3 = ABS(WGAS-WPNEW)
      IF((DUM1.GT.TOL1).OR.(DUM2.GT.TOL1).OR.(DUM3.GT.TOL1)) GOTO 580
        IF(.NOT.CNVRG) WRITE(6,590) TOL1
590     FORMAT(1X,'DROPLET AT STREAM VELOCITY TO WITHIN ',E10.3,' M/S')
        CNVRG = .TRUE.
580   CONTINUE
C
C     NEW QUANTITIES BECOME OLD FOR NEXT TIMESTEP
C
      XPOLD = XPNEW
      YPOLD = YPNEW
      ZPOLD = ZPNEW
C
      UPOLD = UPNEW
      VPOLD = VPNEW
      WPOLD = WPNEW
C
      TLIQ  = TLNEW
      TIME  = TIME + DTIME
C
C     DEBUG OUTPUT FOR TIMESTEP
C
      DUM1 = DIAM * 1.E6
      IF(PRTLIN.AND.INJOUT(3).EQ.1)WRITE(6,600)II,JI,KI,ICNT2,TIME,XPOLD
     1 ,YPOLD,ZPOLD,UPOLD,VPOLD,WPOLD,TLIQ,DUM1,UGAS,VGAS,WGAS,ETAS
600   FORMAT(' ',3I3,I5,E10.3,2F6.3,F6.1,3F7.2,F7.1,F8.2,3F7.2,E11.4)
C
      RETURN
      END
C ----------------------------------------------------------------------
```

```
      SUBROUTINE ICPSET
C
C     Modified from SETPRT by Mark Sheldon for EER, 5/2/85
C
C     PURPOSE:
C       "ICPSET" stands for:
C       "Incineration Cylindrical 3-d model,
C         Printout from subroutine for SETup (ICSSET)"
C
          LOGICAL*1   CASE(60), INCASE
          REAL        NOZDIA, LHELIQ, KNOZ
C
       COMMON/DIMCB/
     1         IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
       COMMON/LIQCB/
     1         TBOIL , TLIQ  , RHOLIQ, LHELIQ, CPLIQ, HCOMLQ
C
       COMMON/NOZCB/
     1   NOZDIA, AFMRAT, KNOZ  , XNOZ  , YNOZ  , ZNOZ
     2       ,UPCOMP, VPCOMP, WPCOMP, UNOZ
C
       COMMON/PARMCB/
     1         ZSAFE , DSAFE , TSAFE , ESAFE , TOL1
     2       ,NDROP , MAXSTP, NRAMP
C
       COMMON/PRTCB/
     1         CASE  , INCASE(80)     , INJOUT(10), INPTYP(10)
     2       ,NPRT1 , NPRT2 , NPRT3
C
       COMMON/BDYCB/
     1         XL(25)     , XBDY(26)   , UBDY(26,15,5), UBDY1(26,15,5)
     2       ,R(15)       , YBDY(16)   , VBDY(25,16,5), VBDY1(25,16,5)
     3       ,DTHETA(5)  , ZBDY(6)     , WBDY(25,15,6), WBDY1(25,15,6)
     4       ,ROTBDY(25,15,6), TWALL(25,15,5) , CYL
C
       COMMON/SWRLCB/
     1         CFORCE(25,15,6), CFREE(25,15,6)
     2       ,BLAYER, RFORCE, SWIRL , TOTLEN, JLAYER, JFORCE
C
C      DEBUG OUTPUT HEADER
C
       WRITE(6,200)
200    FORMAT('1',/,' ','*** DROPLET INJECTION MODEL ***',/)
C
       WRITE(6,220)(CASE(I),I=1,60)
220    FORMAT(1X,60A1)
C
       WRITE(6,240)(INCASE(I),I=1,70)
240    FORMAT(1X,70A1,/)
C
       WRITE(6,260)IX,IY,IZ
260    FORMAT(1X,'SOLUTION GRID: I=',I3,' AXIAL BY J=',I3
     1          ,' RADIAL BY K=',I3,' AZIMUTHAL ZONES',/)
C
```

```
      WRITE(6,270)
270   FORMAT(1X,'ZONE BOUNDARY LOCATIONS:')
C
      WRITE(6,280)
280   FORMAT(4X,'ZONE I,J,K IS BETWEEN XBDY(I) AND XBDY(I+1),ETC.')
C
      I1 = IXPLUS
      IF(IYPLUS.GT.I1) I1 = IYPLUS
      IF(IZPLUS.GT.I1) I1 = IZPLUS
      DO 300 I = 1,I1
        IF(I.LE.IXPLUS.AND.I.LE.IYPLUS.AND.I.LE.IZPLUS)
     1    WRITE(6,310)I,XBDY(I),I,YBDY(I),I,ZBDY(I)
310       FORMAT(4X,'XBDY(',I3,') =',F8.4
     1          ,5X,'YBDY(',I3,') =',F8.4
     2          ,5X,'ZBDY(',I3,') =',F9.4)
C
        IF(I.LE.IXPLUS) GOTO 320
          IF(I.LE.IYPLUS.AND.I.LE.IZPLUS)
     1      WRITE(6,330)I,YBDY(I),I,ZBDY(I)
330         FORMAT(4X,25X,'YBDY(',I3,') =',F8.4
     1                   ,5X,'ZBDY(',I3,') =',F9.4)
C
          IF(I.GT.IYPLUS)
     1      WRITE(6,340)I,ZBDY(I)
340         FORMAT(4X,25X,25X,'ZBDY(',I3,') =',F9.4)
C
          IF(I.GT.IZPLUS)
     1      WRITE(6,350)I,YBDY(I)
350         FORMAT(4X,25X,'YBDY(',I3,') =',F8.4)
320     CONTINUE
C
        IF(I.LE.IYPLUS) GOTO 360
          IF(I.LE.IXPLUS.AND.I.LE.IZPLUS)
     1      WRITE(6,370)I,XBDY(I),I,ZBDY(I)
370         FORMAT(4X,'XBDY(',I3,') =',F8.4
     1         ,5X,25X,'ZBDY(',I3,') =',F9.4)
C
          IF(I.GT.IZPLUS)
     1      WRITE(6,380)I,XBDY(I)
380         FORMAT(4X,'XBDY(',I3,') =',F8.4)
360     CONTINUE
C
        IF(I.LE.IZPLUS) GOTO 390
          IF(I.LE.IXPLUS.AND.I.LE.IYPLUS)
     2      WRITE(6,392)I,XBDY(I),I,YBDY(I)
392         FORMAT(4X,'XBDY(',I3,') =',F8.4
     1               ,5X,'YBDY(',I3,') =',F8.4)
390     CONTINUE
300   CONTINUE
C
      CALL ARRPRT(UBDY1 ,IY    ,IXPLUS,IZ    ,2,1
     1,'AXIAL  GAS VELOCITY AT ZONE BDY, M/S    ')
C
      CALL ARRPRT(VBDY1 ,IX    ,IYPLUS,IZ    ,1,2
     1,'RADIAL GAS VELOCITY AT ZONE BDY, M/S    ')
```

```
C
      CALL ARRPRT(ROTBDY,IX    ,IY    ,IZPLUS,1,2
     1,'ROTATIONAL GAS VEL AT ZONE BDY, M/S     ')
C
      CALL ARRPRT(WBDY1 ,IX    ,IY    ,IZPLUS,1,2
     1,'TANGENTIAL GAS VEL AT ZONE BDY, M/S     ')
C
      CALL ARRPRT(CFREE ,IX    ,IY    ,IZPLUS,1,2
     1,'CONSTANT FOR FREE VORTEX, M**2 /S       ')
C
      CALL ARRPRT(CFORCE,IX    ,IY    ,IZPLUS,1,2
     1,'CONSTANT FOR FORCED VORTEX, S**-1       ')
C
      WRITE(6,510)
510   FORMAT(1X,/,1X,'SWIRL PARAMETERS:')
C
      WRITE(6,520) SWIRL
520   FORMAT(4X,'SWIRL NUMBER=',F10.4)
C
      WRITE(6,530) TOTLEN
530   FORMAT(4X,'TOTAL INCINERATOR LENGTH=',F10.4)
C
      WRITE(6,540) JFORCE, JLAYER
540   FORMAT(4X,'FORCED VORTEX IN INNER',I3,' ZONES (WGAS GOES AS R)'
     1      ,/,4X,'FREE VORTEX IN REMAINING ZONES (WGAS GOES AS 1/R)'
     2      ,/,4X,'BOUNDARY LAYER IN OUTER',I3,' ZONES')
C
      WRITE(6,600)
600   FORMAT(1X,/,1X,'INITIAL DROPLET PROPERTIES:')
C
      WRITE(6,620)TLIQ
620   FORMAT(4X,'INITIAL DROP TEMP     (K) = ',F7.1)
C
      WRITE(6,630)TBOIL
630   FORMAT(4X,'LIQUID BOILING TEMP   (K) = ',F7.1)
C
      WRITE(6,640)RHOLIQ
640   FORMAT(4X,'LIQUID DENSITY (KG M**-3) = ',E10.3)
C
      WRITE(6,650)CPLIQ
650   FORMAT(4X,'LIQUID HEAT CAPACITY (M**2 S**-2 K**-1) = ',E10.3)
C
      WRITE(6,660)LHELIQ
660   FORMAT(4X,'LATENT HEAT OF EVAP. (M**2 S**-2)        = ',E10.3,/)
C
      WRITE(6,740)AFMRAT
740   FORMAT(4X,'AIR/FUEL MASS RATIO=',F7.4)
C
720   CONTINUE
C
      WRITE(6,750)XNOZ,YNOZ,ZNOZ
750   FORMAT(4X,'INJECTION COORDINATES(M): X='
     1          ,F6.3,' Y=',F6.3,' Z=',F8.3)
C
      WRITE(6,800)
```

```
800   FORMAT(1X,/,1X,'PROGRAM PARAMETERS:')
C
      WRITE(6,810) NDROP
810   FORMAT(4X,'NUMBER OF DROPLETS INJECTED =',I8)
C
      WRITE(6,820)MAXSTP
820   FORMAT(4X,'MAXIMUM NUMBER OF STEPS IN LOOP, MAXSTP = ',I10)
C
      WRITE(6,830) NRAMP
830   FORMAT(4X,'TIMESTEP SIZE INCREASED OVER ',I4
     1          ,' STEPS, 1ST ZONE')
C
      WRITE(6,840)ZSAFE
840   FORMAT(4X,'SAFETY FACTOR FOR ZONE TRAVERSE, ZSAFE = ',F7.3)
C
      WRITE(6,850)DSAFE
850   FORMAT(4X,'SAFETY FACTOR FOR DRAG TIMESTEP, DSAFE = ',F7.3)
C
      WRITE(6,860)TSAFE
860   FORMAT(4X,'SAFETY FACTOR FOR TEMP TIMESTEP, TSAFE = ',F7.3)
C
      WRITE(6,870)ESAFE
870   FORMAT(4X,'SAFETY FACTOR FOR EVAP TIMESTEP, ESAFE = ',F7.3,/)
C
      RETURN
      END
C ---------------------------------------------------------------------
      SUBROUTINE ICPGAS
C
C     Modified from GASPRT by Mark Sheldon for EER, 5/3/85
C
C     PURPOSE:
C       "ICPGAS" stands for:
C       "Incineration Cylindrical 3-d model,
C         Printout subroutine for "ICSGAS""
C
          REAL*4 DUMAR(25,15), MDOTIN
          INTEGER     TIMAX
          LOGICAL*1   COMPND(40,20), CASE(60), INCASE
C
      COMMON/DIMCB/
     1       IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
      COMMON/PRTCB/
     1                CASE  , INCASE(80)    , INJOUT(10), INPTYP(10)
     2       ,NPRT1 , NPRT2 , NPRT3
C
      COMMON/INPUT/
     3             V(25,15,5),    TEMP(25,15,5), MDOTIN
     4       ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC   , NPART
     5       ,II    , JI    , KI    , NCMPND, COMPND
C
      COMMON/GASCB/
     1       CPGAS(25,15,5) , DVISCG(25,15,5), TCONDG(25,15,5)
     2       ,FO2   , FN2   , FCO2  , FH2O
```

```
C
C     OUTPUT HEADER
C
      WRITE(6,200)(INCASE(I),I=1,70)
200   FORMAT(1X,70A1)
C
      WRITE(6,220)FO2,FNFN2,FCO2,FH2O
220   FORMAT(1X,/,1X,'MASS FRACTIONS:',/,1X
     1      ,'O2=',F6.4,3X,'N2=',F6.4,3X,'CO2=',F6.4,3X,'H2O=',F6.4)
C
C     INPUT ARRAYS
C
      CALL ARRPRT(TEMP  ,IX    ,IY    ,IZ    ,1,2
     1,'ZONE TEMPERATURE (K)                 ')
C
C     OUTPUT ARRAYS
C
      CALL ARRPRT(CPGAS ,IX    ,IY    ,IZ    ,1,2
     1,'ZONE HEAT CAPACITY (M*M/S/S/K)       ')
C
      CALL ARRPRT(DVISCG,IX    ,IY    ,IZ    ,1,2
     1,'ZONE DYNAMIC VISCOSITY (KG/M/S)      ')
C
      CALL ARRPRTCONDG,IX    ,IY    ,IZ    ,1,2
     1,'ZONE THERMAL CONDUCTIVITY (KG/S/S/S/K) ')
C
      RETURN
      END
C----------------------------------------------------------------------
      SUBROUTINE ICPSPR
C
C     Modified from DRPPRT by Mark Sheldon for EER, 5/3/85
C
C     PURPOSE:
C       "ICPSPR" stands for:
C       "Incineration Cylindrical 3-d model,
C         Printout subroutine for "ICSSPR"
C
          LOGICAL*1   CASE(60), INCASE
          INTEGER        DSTRIB
          REAL        NOZDIA, LOD, KNOZ
C
       COMMON/NOZCB/
     1       NOZDIA, AFMRAT, KNOZ  , XNOZ  , YNOZ  , ZNOZ
     2      ,UPCOMP, VPCOMP, WPCOMP, UNOZ
C
       COMMON/PRTCB/
     1       CASE  , INCASE(80)    , INJOUT(10), INPTYP(10)
     2      ,NPRT1 , NPRT2 , NPRT3
C
       COMMON/DROPCB/
     1       XPOLD, YPOLD, ZPOLD, UPOLD, VPOLD, WPOLD, DRPVEL
     2       XPINIT, YPINIT, ZPINIT, UPINIT, VPINIT, WPINIT
     3      ,DINIT , RNDNUM, SPACIN, C, SPACE, IT, LOD
C
```

```
C     DEBUG OUTPUT HEADER
C
      WRITE(6,110)(CASE(I),I=1,60)
110   FORMAT('1',/,1X,60A1)
C
      WRITE(6,120)(INCASE(I),I=1,70)
120   FORMAT(1X,70A1)
C
      WRITE(6,220)
220   FORMAT(1X,/,1X,'DROPLET INITIAL CONDITIONS:')
C
      WRITE(6,230)DINIT
230   FORMAT(4X,'INITIAL DROP DIAMETER (M) = ',E10.3)
C
      WRITE(6,240)XPINIT,YPINIT,ZPINIT
240   FORMAT(4X,'INITIAL POSITION: X (M)  =',F8.3
     1          ,'  Y (M)  =',F8.3,'  Z (DEG) =',F8.3)
C
      WRITE(6,250)UPINIT,VPINIT,WPINIT
250   FORMAT(4X,'INITIAL VELOCITY: U (M/S)=',F8.3
     1          ,'  V (M/S)=',F8.3,'  W (M/S) =',F8.3,/)
C
      WRITE (6,255) DRPVEL,LOD,SPACIN
255   FORMAT(4X,'INITIAL TOTAL VELOCITY (M/S) =',F10.3/4X,
     1       'INITIAL SPACING = ',F9.3,' DROPLET DIAMETERS'/4X,
     2       'INITIAL SPACING BETWEEN DROPLETS (M)  = ',E10.3)
C
      WRITE(6,290)
290   FORMAT(1X,'DROP TIME HISTORY:',/)
C
      WRITE(6,300)
300   FORMAT(' ','          STEP                        POSITION     '
     1         ,'   VELOCITY (M/S)    TEMP(K)                ')
C
      WRITE(6,310)
310   FORMAT(' ','             # IN   TIME   AXIAL RADIAL ANGLE'
     1         ,' AXIAL RADIAL TANGENT         DIAMETER'
     2         ,'  UGAS   VGAS   WGAS ')
C
      WRITE(6,320)
320   FORMAT(' ',' II JI KI ZONE   (SEC)   X(M)  Y(M) Z(DEG)'
     1         ,'    U       V       W          (MICRON)'
     2         ,' (M/S)  (M/S)  (M/S) ')
C
      RETURN
      END
C----------------------------------------------------------------------
      SUBROUTINE ICPINJ
C
C     Modified from INJPRT by Mark Sheldon for EER, 5/2/85
C
C     PURPOSE:
C       "ICPINJ" stands for:
C       "Incineration Cylindrical 3-d model,
C         Printout for subroutine "ICSINJ""
C
```

```
C
      LOGICAL*1   CASE(60), INCASE
      INTEGER   TIMAX,  DSTMAX, DST2(50,20), DSTRIB
      REAL   LOD
      INTEGER DST(50,20)
C
      COMMON/DIMCB/
     1         IX    , IY    , IZ    , IXPLUS, IYPLUS, IZPLUS
C
      COMMON/INPUT/
     3          V(25,15,5),   TEMP(25,15,5), MDOTIN
     4        ,SUMASS, TIMAX , TEMAX , TEMIN , TAUC   , NPART
     5        ,II    , JI    , KI    , NCMPND, COMPND
C
      COMMON/PRTCB/
     1         CASE  , INCASE(80)     , INJOUT(10), INPTYP(10)
     2        ,NPRT1 , NPRT2 , NPRT3
C
      COMMON/PRINT/
     1         DSTRIB(50,20), DSTMAX, NXMAX, NYMAX, XMEAN, YMEAN, ZMEAN
     2         , XFINAL, YFINAL, NXGRID, NYGRID, STDVX, STDVY, STDVZ
     3         , XMAX, YMAX, ZMAX, XMIN, YMIN, ZMIN
C
      COMMON/DROPCB/
     1         XPOLD, YPOLD, ZPOLD, UPOLD, VPOLD, WPOLD, DRPVEL
     2         XPINIT, YPINIT, ZPINIT, UPINIT, VPINIT, WPINIT
     3        ,DINIT , RNDNUM, SPACIN, C, SPACE, IT, LOD, VINIT1
C
C     OUTPUT -  PRINT INITIAL CONDITIONS AND STATISTICS
C
      WRITE(7,100)
100   FORMAT(1X,/,1X,'INJECTION RESULTS:',/)
C
      WRITE(7,105)(CASE(I),I=1,60)
105   FORMAT(1X,60A1)
      WRITE(7,110)(INCASE(I),I=1,70)
110   FORMAT(1X,70A1)
      WRITE(7,120)
120   FORMAT(1X,/,1X,'DROPLET INITIAL CONDITIONS:')
C
      WRITE(7,130)DINIT
130   FORMAT(4X,'INITIAL DROP DIAMETER (M) = ',E10.3)
C
      WRITE(7,140)XPINIT,YPINIT,ZPINIT
140   FORMAT(4X,'INITIAL POSITION: X (M)  =',F8.3
     1         ,'  Y (M)  =',F8.3,'  Z (DEG) =',F8.3)
C
      WRITE(7,150)UPINIT,VPINIT,WPINIT
150   FORMAT(4X,'INITIAL VELOCITY: U (M/S)=',F8.3
     1         ,'  V (M/S)=',F8.3,'  W (M/S) =',F8.3,/)
C
      WRITE (7,160) VINIT1,LOD,SPACIN
160   FORMAT(4X,'INITIAL TOTAL VELOCITY (M/S) =',F10.3/4X,
     1         'INITIAL SPACING = ',F9.3,' DROPLET DIAMETERS'/4X,
     2         'INITIAL SPACING BETWEEN DROPLETS (M) = ',E10.3)
```

```
C
      WRITE(7,170) TIMAX,XMEAN,YMEAN,ZMEAN
170   FORMAT(/2X,'THE DATA CONTAINS ',I4,' DATA POINTS, WITH THE ',
     1 'AVERAGE EVAPORATION POINT'/2X,'LOCATED AT (',F5.3,',',F5.3,
     2 ',',F7.3,').')
      WRITE(7,180) STDVX,STDVY,STDVZ
180   FORMAT (2X,'THE STANDARD DEVIATIONS ARE (',F5.3,',',F5.3,
     1           ',',F5.1,')')
      WRITE(7,190) XMIN,XMAX,YMIN,YMAX,ZMIN,ZMAX
190   FORMAT (2X,'THE RANGES IN ALL DIRECTIONS ARE ',
     1      'X: (',F5.3,'-',F5.3,')'/36X,'Y: (',F5.3,'-',F5.3,')'/
     2   36X,'Z: (',F5.1,'-',F5.1,')')
      WRITE(7,200) NXGRID,NYGRID,XFINAL,YFINAL
200   FORMAT(2X,'IN THIS GRID, GRID POINTS X = ',I2,' AND Y = ',
     1   I2,/2X,'CORRESPOND'
     2   ,' TO THE PHYSICAL LOCATION (',F5.3,',',F5.3,').')
C
      N = 1
      NP = 20
      WRITE(7,230)
 230  FORMAT(/25X,'DISTRIBUTION OF DROPLET EVAPORATION')
 240  WRITE(7,250) (J,J=N,NP)
 250  FORMAT(/7X,'X',20I4,/4X,'Y')
      DO 280 J = 1,NYMAX
      WRITE(7,260) J,(DSTRIB(I,J),I=N,NP)
 260  FORMAT(3X,I2,3X,20I4)
      DO 270 I = N,NP
      DST2(I,J) = INT(FLOAT(DSTRIB(I,J)) * 10. /FLOAT(DSTMAX))
 270  CONTINUE
 280  CONTINUE
      N = N + 20
      NP = NP + 20
      IF (N.GT.NXMAX) GO TO 290
      GO TO 240
C
 290  N = 1
      NP = 20
      WRITE(7,300)
 300  FORMAT(/20X,'NORMALIZED DISTRIBUTION DENSITY RANGING FROM 1 - 10')
 310  WRITE(7,320) (J,J=N,NP)
 320  FORMAT(/7X,'X',20I4,/4X,'Y')
      DO 340 J = 1,NYMAX
      WRITE(7,330) J,(DST2(I,J),I=N,NP)
 330  FORMAT(3X,I2,3X,20I4)
 340  CONTINUE
      N = N + 20
      NP = NP + 20
      IF(N.GT.NXMAX) GO TO 350
      GO TO 310
C
 350  RETURN
      END
C     ------------------------------------------------------------
C
      SUBROUTINE ARRPRT(ARRAY,NX,NY,NZ,IX,IY,NAME)
```

```
C
C     Written by Mark Sheldon for EER, 5/2/85
C
C     PURPOSE:  ARRPRT ("ARRay PRinTout") outputs a 3-d array
C               (up to 20X20X20) to a file.
C
C     LOCAL VARIABLES
C
      REAL      ARRAY(NX,NY,NZ),ARDUM(26,20,20)
      LOGICAL   LATER
      CHARACTER*1 NAME(40),DIM(3), DUMNAM(3)
C
C     INITIALIZATIONS
C
C      DATA DUMNAM/'I','J','K'/
      DUMNAM(1) = 'I'
      DUMNAM(2) = 'J'
      DUMNAM(3) = 'K'
      NDEC  = 3
      LATER = .FALSE.
C
C     STORE INPUT ARRAY IN DUMMY ARRAY TO BE MANIPULATED
C
      IF(IX.NE.1) GOTO 100
        IF(IY.NE.2) GOTO 110
          IZ = 3
          MX = NX
          MY = NY
          MZ = NZ
          DO 120 K=1,NZ
          DO 120 J=1,NY
          DO 120 I=1,NX
            ARDUM(I,J,K) = ARRAY(I,J,K)
 120      CONTINUE
 110    CONTINUE
        IF(IY.NE.3) GOTO 130
          IZ = 2
          MX = NX
          MY = NZ
          MZ = NY
          DO 140 K=1,NZ
          DO 140 J=1,NY
          DO 140 I=1,NX
            ARDUM(I,K,J) = ARRAY(I,J,K)
 140      CONTINUE
 130    CONTINUE
 100  CONTINUE
C
      IF(IX.NE.2) GOTO 150
        IF(IY.NE.1) GOTO 160
          IZ = 3
          MX = NY
          MY = NX
          MZ = NZ
          DO 170 K=1,NZ
          DO 170 J=1,NY
          DO 170 I=1,NX
            ARDUM(J,I,K) = ARRAY(I,J,K)
170       CONTINUE
160     CONTINUE
        IF(IY.NE.3) GOTO 180
          IZ = 1
          MX = NZ
          MY = NX
          MZ = NY
          DO 190 K=1,NZ
          DO 190 J=1,NY
          DO 190 I=1,NX
            ARDUM(K,I,J) = ARRAY(I,J,K)
190       CONTINUE
180     CONTINUE
150   CONTINUE
C
      IF(IX.NE.3) GOTO 200
        IF(IY.NE.1) GOTO 210
          IZ = 2
          MX = NY
          MY = NZ
          MZ = NX
          DO 220 K=1,NZ
          DO 220 J=1,NY
          DO 220 I=1,NX
            ARDUM(J,K,I) = ARRAY(I,J,K)
220       CONTINUE
210     CONTINUE
        IF(IY.NE.2) GOTO 230
          IZ = 1
          MX = NZ                  20 I
          MY = NY
          MZ = NX
          DO 240 K=1,NZ
          DO 240 J=1,NY
          DO 240 I=1,NX
          ARDUM(K,J,I) = ARRAY(I,J,K)
240       CONTINUE
230     CONTINUE
200   CONTINUE
      WRITE (6,201) MX,MY,MZ
 201  FORMAT(5X,'MX = ',I2,' MY = ',I2,' MZ = ',I2)
C
C     LABELS FOR AXES
C
      DIM(IX) = DUMNAM(1)
      DIM(IY) = DUMNAM(2)
      DIM(IZ) = DUMNAM(3)
C
C     FIND MAX AND MIN ORDER OF MAGNITUDE OF ARRAY ELEMENTS
C
      MAXPOW = 0
      MINPOW = 0
      DO 300 K=1,MZ
      DO 300 J=1,MY
      DO 300 I=1,MX
        IPOW = 0
        DUM1 = ABS(ARDUM(I,J,K))
        DUM2 = DUM1 * 10.**(15 + IABS(IPOW)) - .01
        IF(DUM2.LT.0.00000000)GOTO 300
320     CONTINUE
        IF(DUM1.LT.10.) GOTO 330
          DUM1 = DUM1 * 0.1
          IPOW = IPOW + 1
330     CONTINUE
        IF(DUM1.GE.1.)  GOTO 340
          DUM1 = DUM1 * 10.
          IPOW = IPOW - 1
340     CONTINUE
        IF(DUM1.GE.10.)GOTO 320
        IF(DUM1.LT.1.) GOTO 330
C
        IF(LATER) GOTO 350
          MAXPOW = IPOW
          MINPOW = IPOW
          LATER  = .TRUE.
350     CONTINUE
C
        IF(IPOW.GT.MAXPOW) MAXPOW = IPOW
        IF(IPOW.LT.MINPOW) MINPOW = IPOW
300   CONTINUE
C
C     CHECK MAX SPREAD OF MAGNITUDE IN ARRAY
C
      IOUT = 1
      IDUM1= NDEC + 1
      IDUM2= MAXPOW - MINPOW
      IF(IDUM2.GT.IDUM1) IOUT = 2
C
C     NORMALIZE ARRAY
C
      IF(IOUT.EQ.2)GOTO 400
        DO 410 K=1,MZ
        DO 410 J=1,MY
        DO 410 I=1,MX
          ARDUM(I,J,K) = ARDUM(I,J,K) * 0.100000**(MAXPOW)
410     CONTINUE
400   CONTINUE
C
C     OUTPUT SEQUENCE
C       IF IOUT=1, USE NORMALIZED ARRAY
C       IF IOUT=2, USE ORIGINAL ARRAY WITH EXPONENTIAL FORMAT
C
      DO 500 K=1,MZ
C
      IF(IOUT.EQ.2) GOTO 501
        WRITE(6,510)(NAME(I),I=1,40),DIM(3),K,MAXPOW
     1               ,DIM(2),DIM(1),(I,I=1,MX)
```

```
510     FORMAT(/,' ',40A1,5X,'AT LEVEL ',A1,'=',I3
     1         ,/,5X,'VALUES IN TABLE MUST BE MULTIPLIED BY 1.E',I3
     2         ,/,' ',A1,':  ',A1,'=',25(I3,4X))
501   CONTINUE
C
      IF(IOUT.EQ.1) GOTO 502
        WRITE(6,503)(NAME(I),I=1,40),DIM(3),K
     1                  ,DIM(2),DIM(1),(I,I=1,MX)
503     FORMAT(/,' ',40A1,5X,'AT LEVEL ',A1,'=',I3
     2         ,/,' ',A1,':  ',A1,'=',25(I3,4X))
502   CONTINUE
        IF(IOUT.EQ.2) GOTO 520
          DO 530 J=1,MY
            WRITE(6,540) J,(ARDUM(I,J,K),I=1,MX)
540         FORMAT(' ',I3,25(1X,F6.3))
530       CONTINUE
C
520     CONTINUE
        IF(IOUT.EQ.1) GOTO 500
          DO 560 J=1,MY
            WRITE(6,570) J,(ARDUM(I,J,K),I=1,MX)
570         FORMAT(' ',I3,25(1X,E10.3))
560       CONTINUE
C
500   CONTINUE
      RETURN
      END
```

```
*----------------------------------------------------------------------------:
:  File: DROP3D.OUT                                                   Page  1
: Saved: 01-13-88 at 10:52:13 am
*----------------------------------------------------------------------------,

TYPE C FLAME - EXPERIMENTAL RESULTS
  DROPLET COMPOSITION: 80% XYLENE, 20% FUEL OIL

DROPLET INITIAL CONDITIONS:
   INITIAL DROP DIAMETER (M) =   0.210E-03
   INITIAL POSITION: X (M)  =    0.000  Y (M)  =   0.140  Z (DEG) =    0.000
   INITIAL VELOCITY: U (M/S)=    6.062  V (M/S)=  -3.500  W (M/S) =    0.000

   INITIAL TOTAL VELOCITY (M/S) =      0.000
   INITIAL SPACING =   155.000 DROPLET DIAMETERS
   INITIAL SPACING BETWEEN DROPLETS (M)  =  0.325E-01
DROP TIME HISTORY:

          STEP                POSITION         VELOCITY (M/S)    TEMP(K)
          # IN   TIME    AXIAL RADIAL ANGLE AXIAL RADIAL TANGENT        DIAMETER
UGAS   VGAS   WGAS
 II JI KI ZONE    (SEC)    X(M)  Y(M) Z(DEG)    U       V       W          (MICRON) (
M/S)  (M/S)  (M/S)
  1 11  1     1 0.110E-04 0.000 0.140    0.0   6.06   -3.50   0.00   298.2  210.00
-0.15   -5.60    0.00 0.9968E+00
  1 11  1     2 0.110E-04 0.000 0.140    0.0   6.06   -3.50   0.00   298.2  210.00
-0.13   -5.61    0.00 0.9968E+00
  1 11  1     1 0.334E-03 0.002 0.139  360.0   6.03   -3.53   0.00   304.9  210.00
 0.08   -5.81    0.00 0.9968E+00
  1 11  1     2 0.334E-03 0.004 0.138  360.0   6.03   -3.53   0.00   304.9  210.00
 0.29   -6.01    0.00 0.9968E+00
  1 11  1     1 0.530E-03 0.005 0.137    0.0   6.01   -3.54   0.00   308.8  210.00
 0.41   -6.13    0.00 0.9968E+00
  1 11  1     2 0.667E-03 0.006 0.136    0.0   6.00   -3.55   0.00   311.5  210.00
 0.54   -6.24    0.00 0.9968E+00
  1 11  1     1 0.785E-03 0.007 0.136  360.0   5.99   -3.57   0.00   313.9  210.00
 0.61   -6.32    0.00 0.9968E+00
  1 11  1     2 0.903E-03 0.008 0.135  360.0   5.98   -3.58   0.00   316.2  210.00
 0.69   -6.39    0.00 0.9968E+00
  1 11  1     3 0.102E-02 0.009 0.135  360.0   5.97   -3.59   0.00   318.5  210.00
 0.76   -6.46    0.00 0.9968E+00
  1 11  1     4 0.114E-02 0.009 0.135  360.0   5.96   -3.60   0.00   320.8  210.00
 0.84   -6.54    0.00 0.9968E+00
  1 11  1     5 0.126E-02 0.010 0.134  360.0   5.96   -3.62   0.00   323.1  210.00
 0.91   -6.61    0.00 0.9968E+00
  1 11  1     6 0.126E-02 0.010 0.134  360.0   5.96   -3.62   0.00   323.2  210.00
 0.91   -6.61    0.00 0.9968E+00
  2 11  1     1 0.159E-02 0.012 0.133  360.0   5.93   -3.65   0.00   329.9  210.00
 0.70   -9.14   -3.05 0.9968E+00
  2 11  1     2 0.193E-02 0.014 0.132  360.0   5.91   -3.71  -0.01   337.2  210.00
 0.49   -9.01   -3.08 0.9968E+00
  2 11  1     3 0.227E-02 0.016 0.130  360.0   5.88   -3.77  -0.03   344.3  210.00
 0.28   -8.89   -3.11 0.9968E+00
  2 11  1     4 0.260E-02 0.018 0.129  360.0   5.86   -3.83  -0.04   351.5  210.00
 0.07   -8.76   -3.14 0.9968E+00
  2 11  1     5 0.294E-02 0.020 0.128  360.0   5.83   -3.88  -0.05   358.5  210.00
-0.14   -8.63   -3.17 0.9968E+00
  2 11  1     6 0.295E-02 0.020 0.128  360.0   5.83   -3.88  -0.05   358.8  210.00
-0.15   -8.62   -3.17 0.9968E+00
  3 11  1     1 0.329E-02 0.022 0.126  360.0   5.80   -3.94  -0.07   366.0  210.00
 0.21   -0.92   -3.20 0.9968E+00
  3 11   1    2 0.364E-02 0.024 0.125 360.0   5.75  -3.92  -0.08  372.8  210.00
 0.58   -0.64   -3.24 0.9968E+00
  3 11   1    3 0.398E-02 0.026 0.124 360.0   5.71  -3.91  -0.10  379.6  210.00
 0.94   -0.37   -3.27 0.9968E+00
  3 11   1    4 0.432E-02 0.028 0.122 359.9   5.67  -3.89  -0.12  386.2  210.00
 1.30   -0.10   -3.31 0.9967E+00
  3 11   1    5 0.467E-02 0.030 0.121 359.9   5.64  -3.88  -0.14  392.8  210.00
 1.65    0.17   -3.34 0.9967E+00
  3 11   1    6 0.469E-02 0.030 0.121 359.9   5.63  -3.88  -0.14  393.2  210.00
 1.68    0.19   -3.35 0.9967E+00
  4 11   1    1 0.474E-02 0.030 0.121 359.9   5.63  -3.87  -0.14  394.2  210.00
 1.60   -5.52   -3.35 0.9967E+00
  4 11   1    2 0.480E-02 0.031 0.121 359.9   5.63  -3.88  -0.15  395.2  210.00
 1.53   -5.49   -3.36 0.9967E+00
  4 11   1    3 0.485E-02 0.031 0.120 359.9   5.62  -3.88  -0.15  396.2  210.00
 1.45   -5.46   -3.36 0.9967E+00
  4 11   1    4 0.490E-02 0.031 0.120 359.9   5.62  -3.88  -0.15  397.1  210.00
 1.38   -5.42   -3.37 0.9967E+00
  4 11   1    5 0.495E-02 0.031 0.120 359.9   5.62  -3.88  -0.16  398.1  210.00
 1.30   -5.39   -3.37 0.9967E+00
  4 10   1    1 0.526E-02 0.033 0.119 359.9   5.60  -3.90  -0.18  403.7  210.00
-0.84   -5.29   -3.53 0.9967E+00
  4 10   1    2 0.556E-02 0.035 0.118 359.9   5.57  -3.92  -0.20  409.6  210.00
-0.92   -5.19   -3.57 0.9967E+00
  4 10   1    3 0.586E-02 0.037 0.116 359.8   5.54  -3.93  -0.22  415.5  210.00
-1.00   -5.09   -3.61 0.9967E+00
  4 10   1    4 0.617E-02 0.038 0.115 359.8   5.51  -3.94  -0.23  421.3  210.00
-1.07   -4.99   -3.64 0.9967E+00
  4 10   1    5 0.647E-02 0.040 0.114 359.8   5.48  -3.96  -0.25  421.8  208.90
-1.15   -4.89   -3.68 0.9967E+00
  4 10   1    6 0.648E-02 0.040 0.114 359.8   5.48  -3.96  -0.26  421.8  208.85
-1.15   -4.89   -3.68 0.9967E+00
  5 10   1    1 0.684E-02 0.042 0.113 359.7   5.48  -3.96  -0.26  421.8  207.40
-1.53   -8.73   -3.73 0.9967E+00
  5 10   1    2 0.720E-02 0.044 0.111 359.7   5.47  -3.97  -0.27  421.8  205.91
-1.90   -8.66   -3.78 0.9967E+00
  5 10   1    3 0.755E-02 0.046 0.110 359.6   5.46  -3.99  -0.27  421.8  204.41
-2.27   -8.60   -3.83 0.9967E+00
  5 10   1    4 0.790E-02 0.048 0.108 359.6   5.45  -4.00  -0.28  421.8  202.92
-2.63   -8.54   -3.87 0.9968E+00
  5 10   1    5 0.824E-02 0.050 0.107 359.5   5.45  -4.01  -0.29  421.8  201.43
-2.99   -8.48   -3.92 0.9968E+00
  5 10   1    6 0.831E-02 0.050 0.107 359.5   5.44  -4.01  -0.29  421.8  201.10
-3.07   -8.47   -3.93 0.9968E+00
  6 10   1    1 0.865E-02 0.052 0.105 359.4   5.44  -4.03  -0.30  421.8  199.61
-2.93   -3.20   -4.98 0.9968E+00
  6 10   1    2 0.898E-02 0.054 0.104 359.4   5.43  -4.03  -0.31  421.8  198.15
-2.79   -3.11   -5.05 0.9968E+00
  6 10   1    3 0.931E-02 0.055 0.103 359.3   5.42  -4.03  -0.32  421.8  196.70
-2.65   -3.02   -5.11 0.9969E+00
  6 10   1    4 0.963E-02 0.057 0.101 359.3   5.41  -4.03  -0.33  421.8  195.27
-2.52   -2.93   -5.18 0.9969E+00
  6 10   1    5 0.995E-02 0.059 0.100 359.2   5.40  -4.03  -0.34  421.8  193.86
-2.39   -2.85   -5.24 0.9969E+00
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  6 10  1    6 0.102E-01 0.060 0.099 359.2   5.40  -4.03  -0.35  421.8  192.93
-2.30   -2.79   -5.29 0.9969E+00
  7 10  1    1 0.105E-01 0.062 0.098 359.1   5.39  -4.03  -0.36  421.8  191.53
-1.92   -3.73   -6.42 0.9969E+00
  7 10  1    2 0.108E-01 0.063 0.097 359.1   5.38  -4.03  -0.38  421.8  190.13
-1.54   -3.91   -6.51 0.9970E+00
  7 10  1    3 0.111E-01 0.065 0.096 359.0   5.38  -4.04  -0.39  421.8  188.75
-1.17   -4.09   -6.59 0.9970E+00
  7 10  1    4 0.114E-01 0.067 0.094 358.9   5.37  -4.04  -0.41  421.8  187.40
-0.80   -4.27   -6.67 0.9970E+00
  7 10  1    5 0.117E-01 0.068 0.093 358.8   5.37  -4.04  -0.43  421.8  186.06
-0.44   -4.45   -6.76 0.9970E+00
  7 10  1    6 0.120E-01 0.070 0.092 358.8   5.36  -4.04  -0.45  421.8  184.74
-0.08   -4.62   -6.85 0.9970E+00
  7 10  1    7 0.120E-01 0.070 0.092 358.7   5.36  -4.04  -0.45  421.8  184.52
-0.02   -4.65   -6.86 0.9971E+00
  8 10  1    1 0.121E-01 0.070 0.092 358.7   5.36  -4.04  -0.46  421.8  184.20
-0.08   -1.03   -8.03 0.9971E+00
  8 10  1    2 0.122E-01 0.071 0.091 358.7   5.36  -4.04  -0.46  421.8  183.87
-0.13   -0.93   -8.05 0.9971E+00
  8 10  1    3 0.122E-01 0.071 0.091 358.7   5.36  -4.04  -0.47  421.8  183.55
-0.19   -0.83   -8.08 0.9971E+00
  8 10  1    4 0.123E-01 0.071 0.091 358.7   5.36  -4.04  -0.47  421.8  183.22
-0.25   -0.73   -8.10 0.9971E+00
  8 10  1    5 0.124E-01 0.072 0.090 358.6   5.36  -4.04  -0.48  421.8  182.90
-0.30   -0.63   -8.13 0.9971E+00
  8 10  1    6 0.124E-01 0.072 0.090 358.6   5.36  -4.04  -0.48  421.8  182.57
-0.36   -0.53   -8.15 0.9971E+00
  8 10  1    7 0.125E-01 0.073 0.090 358.6   5.36  -4.04  -0.49  421.8  182.39
-0.41   -0.48   -8.17 0.9971E+00
  8  9  1    1 0.127E-01 0.074 0.089 358.6   5.35  -4.04  -0.50  421.8  181.38
-0.13   -0.37   -9.53 0.9971E+00
  8  9  1    2 0.129E-01 0.075 0.088 358.5   5.35  -4.04  -0.52  421.8  180.36
-0.10   -0.27   -9.62 0.9971E+00
  8  9  1    3 0.131E-01 0.076 0.087 358.4   5.34  -4.03  -0.54  421.8  179.34
-0.08   -0.17   -9.71 0.9971E+00
  8  9  1    4 0.133E-01 0.077 0.087 358.3   5.34  -4.03  -0.56  421.8  178.32
-0.05   -0.07   -9.81 0.9971E+00
  8  9  1    5 0.135E-01 0.078 0.086 358.3   5.34  -4.03  -0.59  421.8  177.32
-0.03    0.03   -9.90 0.9972E+00
  8  9  1    6 0.137E-01 0.079 0.085 358.2   5.34  -4.03  -0.61  421.8  176.31
 0.00    0.12   -9.99 0.9972E+00
  8  9  1    7 0.139E-01 0.080 0.084 358.1   5.33  -4.02  -0.63  421.8  175.45
 0.02    0.21  -10.07 0.9972E+00
  9  9  1    1 0.140E-01 0.081 0.084 358.1   5.33  -4.02  -0.64  421.8  174.67
 0.17   -3.70  -10.14 0.9972E+00
  9  9  1    2 0.142E-01 0.082 0.083 358.0   5.33  -4.02  -0.66  421.8  173.90
 0.33   -3.56  -10.22 0.9972E+00
  9  9  1    3 0.143E-01 0.082 0.083 357.9   5.33  -4.02  -0.68  421.8  173.13
 0.48   -3.42  -10.29 0.9972E+00
  9  9  1    4 0.145E-01 0.083 0.082 357.9   5.33  -4.02  -0.70  421.8  172.37
 0.63   -3.28  -10.37 0.9972E+00
  9  9  1    5 0.146E-01 0.084 0.081 357.8   5.32  -4.01  -0.72  421.8  171.61
 0.78   -3.15  -10.44 0.9972E+00
  9  9  1    6 0.147E-01 0.085 0.081 357.7   5.32  -4.01  -0.73  421.8  170.86
 0.93  -3.01 -10.52 0.9973E+00
  9  9  1     7 0.149E-01 0.086 0.080 357.6   5.32  -4.01  -0.75  421.8  170.11
 1.08  -2.88 -10.60 0.9973E+00
  9  9  1     8 0.149E-01 0.086 0.080 357.6   5.32  -4.01  -0.76  421.8  169.83
 1.23  -2.83 -10.62 0.9973E+00
  9  8  1     1 0.150E-01 0.087 0.080 357.6   5.32  -4.01  -0.77  421.8  169.35
10.07  -2.59 -10.36 0.9973E+00
  9  8  1     2 0.151E-01 0.087 0.079 357.5   5.32  -4.01  -0.78  421.8  168.87
10.06  -2.36 -10.41 0.9973E+00
  9  8  1     3 0.152E-01 0.088 0.079 357.5   5.32  -4.00  -0.79  421.8  168.40
10.05  -2.13 -10.45 0.9973E+00
  9  8  1     4 0.153E-01 0.088 0.079 357.4   5.32  -4.00  -0.81  421.8  167.93
10.04  -1.90 -10.50 0.9973E+00
  9  8  1     5 0.154E-01 0.089 0.078 357.3   5.32  -4.00  -0.82  421.8  167.45
10.03  -1.67 -10.55 0.9973E+00
  9  8  1     6 0.155E-01 0.089 0.078 357.3   5.33  -4.00  -0.83  421.8  166.98
10.02  -1.44 -10.60 0.9973E+00
  9  8  1     7 0.156E-01 0.090 0.078 357.2   5.33  -3.99  -0.84  421.8  166.51
10.01  -1.21 -10.64 0.9973E+00
  9  8  1     8 0.156E-01 0.090 0.077 357.2   5.33  -3.99  -0.85  421.8  166.14
10.00  -1.03 -10.68 0.9973E+00
 10  8  1     1 0.159E-01 0.091 0.076 357.1   5.33  -3.98  -0.88  421.8  164.90
10.38   0.12 -10.81 0.9973E+00
 10  8  1     2 0.161E-01 0.092 0.075 356.9   5.33  -3.97  -0.90  421.8  163.67
10.75   0.32 -10.94 0.9974E+00
 10  8  1     3 0.163E-01 0.094 0.075 356.8   5.33  -3.96  -0.93  421.8  162.43
11.12   0.51 -11.06 0.9974E+00
 10  8  1     4 0.165E-01 0.095 0.074 356.6   5.34  -3.95  -0.96  421.8  161.20
11.48   0.70 -11.19 0.9974E+00
 10  8  1     5 0.167E-01 0.096 0.073 356.4   5.34  -3.94  -0.99  421.8  159.98
11.83   0.89 -11.32 0.9974E+00
 10  8  1     6 0.170E-01 0.097 0.072 356.3   5.34  -3.93  -1.02  421.8  158.76
12.18   1.07 -11.45 0.9974E+00
 10  8  1     7 0.172E-01 0.098 0.071 356.1   5.35  -3.92  -1.04  421.8  157.54
12.53   1.25 -11.58 0.9975E+00
 10  8  1     8 0.174E-01 0.099 0.070 355.9   5.35  -3.90  -1.07  421.8  156.33
12.87   1.43 -11.72 0.9975E+00
 10  8  1     9 0.175E-01 0.100 0.070 355.8   5.35  -3.90  -1.09  421.8  155.69
13.12   1.52 -11.79 0.9975E+00
 11  7  1     1 0.178E-01 0.102 0.069 355.6   5.36  -3.88  -1.13  421.8  153.94
16.60   1.07  -9.43 0.9975E+00
 11  7  1     2 0.180E-01 0.103 0.068 355.3   5.37  -3.86  -1.15  421.8  152.20
16.51   1.31  -9.58 0.9975E+00
 11  7  1     3 0.183E-01 0.104 0.067 355.1   5.39  -3.84  -1.18  421.8  150.48
16.41   1.55  -9.73 0.9976E+00
 11  7  1     4 0.186E-01 0.106 0.066 354.8   5.40  -3.82  -1.21  421.8  148.78
16.32   1.78  -9.88 0.9976E+00
 11  7  1     5 0.188E-01 0.107 0.065 354.5   5.41  -3.80  -1.24  421.8  147.11
16.24   2.00 -10.03 0.9976E+00
 11  7  1     6 0.191E-01 0.109 0.064 354.3   5.42  -3.78  -1.27  421.8  145.46
16.15   2.22 -10.18 0.9977F+00
 11  7  1     7 0.193E-01 0.110 0.063 354.0   5.43  -3.76  -1.30  421.8  143.82
16.06   2.43 -10.33 0.9977E+00
 11  7  1     8 0.196E-01 0.111 0.062 353.7   5.44  -3.74  -1.33  421.8  142.21
15.98   2.64 -10.48 0.9977E+00
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 11  7  1     9 0.198E-01 0.113 0.061 353.4    5.46  -3.72   -1.36  421.8  140.62
15.90    2.84 -10.63 0.9977E+00
 11  7  1    10 0.200E-01 0.114 0.060 353.1    5.47  -3.70   -1.39  421.8  139.04
15.82    3.03 -10.79 0.9978E+00
 11  7  1    11 0.201E-01 0.115 0.060 353.0    5.47  -3.69   -1.40  421.8  138.55
15.74    3.09 -10.83 0.9978E+00
 11  6  1     1 0.202E-01 0.115 0.060 352.9    5.47  -3.68   -1.42  421.8  137.98
15.26    3.14  -9.21 0.9978E+00
 11  6  1     2 0.203E-01 0.116 0.059 352.8    5.48  -3.68   -1.43  421.8  137.43
15.24    3.19  -9.26 0.9978E+00
 11  6  1     3 0.203E-01 0.116 0.059 352.7    5.48  -3.67   -1.44  421.8  136.88
15.23    3.24  -9.30 0.9978E+00
 11  6  1     4 0.204E-01 0.117 0.059 352.6    5.48  -3.66   -1.45  421.8  136.33
15.21    3.29  -9.35 0.9978E+00
 11  6  1     5 0.205E-01 0.117 0.059 352.5    5.49  -3.65   -1.46  421.8  135.79
15.20    3.34  -9.39 0.9978E+00
 11  6  1     6 0.206E-01 0.118 0.058 352.4    5.49  -3.64   -1.47  421.8  135.24
15.18    3.39  -9.44 0.9978E+00
 11  6  1     7 0.206E-01 0.118 0.058 352.3    5.49  -3.64   -1.48  421.8  134.70
15.17    3.43  -9.48 0.9979E+00
 11  6  1     8 0.207E-01 0.118 0.058 352.2    5.50  -3.63   -1.50  421.8  134.17
15.15    3.48  -9.53 0.9979E+00
 11  6  1     9 0.208E-01 0.119 0.057 352.0    5.50  -3.62   -1.51  421.8  133.63
15.14    3.53  -9.57 0.9979E+00
 11  6  1    10 0.209E-01 0.119 0.057 351.9    5.50  -3.61   -1.52  421.8  133.10
15.12    3.57  -9.61 0.9979E+00
 11  6  1    11 0.209E-01 0.120 0.057 351.8    5.51  -3.60   -1.53  421.8  132.56
15.11    3.62  -9.66 0.9979E+00
 11  6  1    12 0.210E-01 0.120 0.057 351.7    5.51  -3.59   -1.54  421.8  132.06
15.10    3.66  -9.70 0.9979E+00
 12  6  1     1 0.211E-01 0.121 0.056 351.5    5.52  -3.57   -1.57  421.8  130.97
15.06    3.37  -7.83 0.9979E+00
 12  6  1     2 0.213E-01 0.122 0.056 351.3    5.52  -3.55   -1.59  421.8  129.91
15.02    3.47  -7.91 0.9979E+00
 12  6  1     3 0.214E-01 0.122 0.055 351.0    5.53  -3.53   -1.61  421.8  128.87
14.98    3.56  -7.98 0.9979E+00
 12  6  1     4 0.216E-01 0.123 0.055 350.8    5.54  -3.51   -1.63  421.8  127.83
14.94    3.66  -8.05 0.9980E+00
 12  6  1     5 0.217E-01 0.124 0.054 350.6    5.54  -3.49   -1.65  421.8  126.80
14.91    3.75  -8.12 0.9980E+00
 12  6  1     6 0.219E-01 0.125 0.054 350.3    5.55  -3.47   -1.67  421.8  125.78
14.87    3.84  -8.20 0.9980E+00
 12  6  1     7 0.220E-01 0.125 0.053 350.1    5.56  -3.45   -1.69  421.8  124.77
14.83    3.93  -8.27 0.9980E+00
 12  6  1     8 0.221E-01 0.126 0.053 349.8    5.56  -3.43   -1.71  421.8  123.77
14.80    4.02  -8.34 0.9980E+00
 12  6  1     9 0.222E-01 0.127 0.052 349.6    5.57  -3.41   -1.73  421.8  122.78
14.76    4.10  -8.41 0.9980E+00
 12  6  1    10 0.224E-01 0.128 0.052 349.4    5.58  -3.39   -1.75  421.8  121.80
14.73    4.18  -8.48 0.9980E+00
 12  6  1    11 0.225E-01 0.128 0.051 349.1    5.58  -3.37   -1.76  421.8  120.82
14.69    4.26  -8.55 0.9981E+00
 12  6  1    12 0.226E-01 0.129 0.051 348.9    5.59  -3.35   -1.78  421.8  119.86
14.66    4.34  -8.62 0.9981E+00
 12  6  1    13 0.227E-01 0.130 0.051 348.6    5.60  -3.33   -1.80  421.8  118.90
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14.63    4.42  -8.69 0.9981E+00
 12  6   1   14 0.229E-01 0.130 0.050 348.4   5.60  -3.31  -1.82  421.8  117.96
14.59    4.50  -8.76 0.9981E+00
 12  6   1   15 0.229E-01 0.131 0.050 348.2   5.61  -3.29  -1.83  421.8  117.38
14.56    4.54  -8.80 0.9981E+00
 12  5   1    1 0.230E-01 0.132 0.050 348.0   5.61  -3.28  -1.85  421.8  116.55
12.94    4.63  -5.44 0.9981E+00
 12  5   1    2 0.231E-01 0.132 0.049 347.8   5.61  -3.26  -1.86  421.8  115.76
12.92    4.72  -5.47 0.9981E+00
 12  5   1    3 0.232E-01 0.133 0.049 347.6   5.62  -3.24  -1.87  421.8  114.98
12.89    4.80  -5.51 0.9982E+00
 12  5   1    4 0.233E-01 0.133 0.049 347.4   5.62  -3.22  -1.89  421.8  114.20
12.86    4.88  -5.54 0.9982E+00
 12  5   1    5 0.234E-01 0.134 0.048 347.2   5.63  -3.21  -1.90  421.8  113.43
12.84    4.96  -5.58 0.9982E+00
 12  5   1    6 0.235E-01 0.134 0.048 347.0   5.63  -3.19  -1.91  421.8  112.67
12.81    5.04  -5.61 0.9982E+00
 12  5   1    7 0.236E-01 0.135 0.048 346.8   5.64  -3.17  -1.92  421.8  111.91
12.79    5.12  -5.65 0.9982E+00
 12  5   1    8 0.237E-01 0.135 0.048 346.6   5.64  -3.15  -1.94  421.8  111.16
12.77    5.20  -5.68 0.9982E+00
 12  5   1    9 0.238E-01 0.136 0.047 346.3   5.64  -3.13  -1.95  421.8  110.41
12.74    5.27  -5.72 0.9982E+00
 12  5   1   10 0.239E-01 0.136 0.047 346.1   5.65  -3.12  -1.96  421.8  109.66
12.72    5.35  -5.75 0.9982E+00
 12  5   1   11 0.240E-01 0.137 0.047 345.9   5.65  -3.10  -1.98  421.8  108.93
12.69    5.42  -5.78 0.9983E+00
 12  5   1   12 0.241E-01 0.137 0.046 345.7   5.66  -3.08  -1.99  421.8  108.20
12.67    5.49  -5.82 0.9983E+00
 12  5   1   13 0.241E-01 0.138 0.046 345.5   5.66  -3.06  -2.00  421.8  107.47
12.65    5.56  -5.85 0.9983E+00
 12  5   1   14 0.242E-01 0.138 0.046 345.3   5.66  -3.04  -2.02  421.8  106.75
12.63    5.63  -5.88 0.9983E+00
 12  5   1   15 0.243E-01 0.139 0.046 345.1   5.67  -3.02  -2.03  421.8  106.03
12.60    5.70  -5.92 0.9983E+00
 12  5   1   16 0.244E-01 0.139 0.045 344.9   5.67  -3.00  -2.04  421.8  105.33
12.58    5.76  -5.95 0.9983E+00
 12  5   1   17 0.245E-01 0.140 0.045 344.7   5.67  -2.98  -2.06  421.8  104.62
12.56    5.83  -5.98 0.9983E+00
 12  5   1   18 0.245E-01 0.140 0.045 344.5   5.68  -2.97  -2.07  421.8  104.07
12.54    5.88  -6.00 0.9983E+00
 13  5   1    1 0.246E-01 0.140 0.045 344.3   5.68  -2.94  -2.08  421.8  103.34
12.56    3.66  -5.03 0.9983E+00
 13  5   1    2 0.247E-01 0.141 0.044 344.1   5.68  -2.93  -2.09  421.8  102.64
12.59    3.62  -5.06 0.9984E+00
 13  5   1    3 0.248E-01 0.141 0.044 343.9   5.69  -2.91  -2.10  421.8  101.95
12.61    3.59  -5.09 0.9984E+00
 13  5   1    4 0.249E-01 0.142 0.044 343.6   5.69  -2.89  -2.11  421.8  101.26
12.63    3.55  -5.11 0.9984E+00
 13  5   1    5 0.249E-01 0.142 0.044 343.4   5.70  -2.87  -2.12  421.8  100.58
12.65    3.52  -5.14 0.9984E+00
 13  5   1    6 0.250E-01 0.143 0.044 343.2   5.70  -2.86  -2.13  421.8   99.91
12.67    3.49  -5.16 0.9984E+00
 13  5   1    7 0.251E-01 0.143 0.043 343.0   5.70  -2.84  -2.14  421.8   99.24
12.69    3.46  -5.19 0.9984E+00
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 13   5   1     8 0.252E-01 0.144 0.043 342.8    5.71   -2.82   -2.15   421.8    98.57
12.71     3.42   -5.22 0.9984E+00
 13   5   1     9 0.252E-01 0.144 0.043 342.6    5.71   -2.80   -2.16   421.8    97.91
12.73     3.39   -5.24 0.9984E+00
 13   5   1    10 0.253E-01 0.144 0.043 342.4    5.72   -2.79   -2.17   421.8    97.26
12.74     3.36   -5.27 0.9984E+00
 13   5   1    11 0.254E-01 0.145 0.043 342.2    5.72   -2.77   -2.18   421.8    96.61
12.76     3.33   -5.29 0.9984E+00
 13   5   1    12 0.254E-01 0.145 0.042 341.9    5.73   -2.76   -2.19   421.8    95.97
12.78     3.30   -5.31 0.9985E+00
 13   5   1    13 0.255E-01 0.146 0.042 341.7    5.73   -2.74   -2.20   421.8    95.33
12.80     3.27   -5.34 0.9985E+00
 13   5   1    14 0.256E-01 0.146 0.042 341.5    5.73   -2.72   -2.21   421.8    94.69
12.82     3.24   -5.36 0.9985E+00
 13   5   1    15 0.257E-01 0.146 0.042 341.3    5.74   -2.71   -2.22   421.8    94.07
12.84     3.22   -5.39 0.9985E+00
 13   5   1    16 0.257E-01 0.147 0.042 341.1    5.74   -2.69   -2.23   421.8    93.44
12.85     3.19   -5.41 0.9985E+00
 13   5   1    17 0.258E-01 0.147 0.041 340.9    5.75   -2.68   -2.24   421.8    92.82
12.87     3.16   -5.43 0.9985E+00
 13   5   1    18 0.259E-01 0.148 0.041 340.7    5.75   -2.66   -2.25   421.8    92.21
12.89     3.14   -5.46 0.9985E+00
 13   5   1    19 0.259E-01 0.148 0.041 340.5    5.76   -2.65   -2.26   421.8    91.60
12.90     3.11   -5.48 0.9985E+00
 13   5   1    20 0.260E-01 0.148 0.041 340.3    5.76   -2.63   -2.27   421.8    91.00
12.92     3.09   -5.50 0.9985E+00
 13   5   1    21 0.260E-01 0.149 0.041 340.1    5.76   -2.62   -2.28   421.8    90.40
12.94     3.06   -5.52 0.9985E+00
 13   5   1    22 0.261E-01 0.149 0.041 339.9    5.77   -2.60   -2.29   421.8    89.80
12.95     3.04   -5.55 0.9986E+00
 13   5   1    23 0.262E-01 0.149 0.040 339.7    5.77   -2.59   -2.30   421.8    89.21
12.97     3.01   -5.57 0.9986E+00
 13   5   1    24 0.262E-01 0.150 0.040 339.5    5.78   -2.57   -2.31   421.8    88.63
12.99     2.99   -5.59 0.9986E+00
 13   5   1    25 0.263E-01 0.150 0.040 339.3    5.78   -2.56   -2.32   421.8    88.05
13.00     2.97   -5.61 0.9986E+00
 13   4   1     1 0.264E-01 0.151 0.040 339.0    5.79   -2.54   -2.34   421.8    87.08
12.13     2.97   -4.39 0.9986E+00
 13   4   1     2 0.264E-01 0.151 0.040 338.8    5.79   -2.52   -2.35   421.8    86.49
12.15     3.00   -4.41 0.9986E+00
 13   4   1     3 0.265E-01 0.151 0.040 338.6    5.80   -2.51   -2.36   421.8    85.90
12.17     3.02   -4.42 0.9986E+00
 13   4   1     4 0.266E-01 0.152 0.039 338.4    5.80   -2.49   -2.36   421.8    85.32
12.19     3.04   -4.44 0.9986E+00
 13   4   1     5 0.266E-01 0.152 0.039 338.2    5.80   -2.48   -2.37   421.8    84.74
12.22     3.06   -4.45 0.9986E+00
 13   4   1     6 0.267E-01 0.152 0.039 338.1    5.81   -2.46   -2.38   421.8    84.17
12.24     3.08   -4.47 0.9987E+00
 13   4   1     7 0.267E-01 0.153 0.039 337.9    5.81   -2.45   -2.39   421.8    83.60
12.26     3.10   -4.48 0.9987E+00
 13   4   1     8 0.268E-01 0.153 0.039 337.7    5.82   -2.43   -2.39   421.8    83.04
12.28     3.12   -4.50 0.9987E+00
 13   4   1     9 0.268E-01 0.153 0.039 337.5    5.82   -2.42   -2.40   421.8    82.47
12.30     3.14   -4.51 0.9987E+00
 13   4   1    10 0.269E-01 0.154 0.039 337.3    5.82   -2.40   -2.41   421.8    81.92
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12.32    3.16  -4.53 0.9987E+00
 13  4   1   11 0.269E-01 0.154 0.039 337.1    5.83   -2.39   -2.42  421.8    81.37
12.34    3.18  -4.54 0.9987E+00
 13  4   1   12 0.270E-01 0.154 0.038 337.0    5.83   -2.37   -2.42  421.8    80.82
12.36    3.20  -4.56 0.9987E+00
 13  4   1   13 0.270E-01 0.154 0.038 336.8    5.83   -2.36   -2.43  421.8    80.27
12.38    3.21  -4.57 0.9987E+00
 13  4   1   14 0.271E-01 0.155 0.038 336.6    5.84   -2.34   -2.43  421.8    79.73
12.40    3.23  -4.58 0.9987E+00
 13  4   1   15 0.271E-01 0.155 0.038 336.4    5.84   -2.33   -2.44  421.8    79.20
12.42    3.25  -4.60 0.9987E+00
 13  4   1   16 0.272E-01 0.155 0.038 336.3    5.85   -2.32   -2.45  421.8    78.66
12.44    3.26  -4.61 0.9987E+00
 13  4   1   17 0.272E-01 0.156 0.038 336.1    5.85   -2.30   -2.45  421.8    78.13
12.46    3.28  -4.62 0.9987E+00
 13  4   1   18 0.273E-01 0.156 0.038 335.9    5.85   -2.29   -2.46  421.8    77.61
12.47    3.30  -4.64 0.9988E+00
 13  4   1   19 0.273E-01 0.156 0.038 335.7    5.86   -2.28   -2.46  421.8    77.09
12.49    3.31  -4.65 0.9988E+00
 13  4   1   20 0.273E-01 0.156 0.038 335.6    5.86   -2.26   -2.47  421.8    76.57
12.51    3.33  -4.66 0.9988E+00
 13  4   1   21 0.274E-01 0.157 0.037 335.4    5.87   -2.25   -2.48  421.8    76.06
12.53    3.34  -4.68 0.9988E+00
 13  4   1   22 0.274E-01 0.157 0.037 335.2    5.87   -2.24   -2.48  421.8    75.55
12.55    3.36  -4.69 0.9988E+00
 13  4   1   23 0.275E-01 0.157 0.037 335.1    5.87   -2.22   -2.49  421.8    75.05
12.56    3.37  -4.70 0.9988E+00
 13  4   1   24 0.275E-01 0.157 0.037 334.9    5.88   -2.21   -2.49  421.8    74.54
12.58    3.39  -4.71 0.9988E+00
 13  4   1   25 0.276E-01 0.158 0.037 334.8    5.88   -2.20   -2.50  421.8    74.05
12.60    3.40  -4.72 0.9988E+00
 14  4   1    1 0.280E-01 0.160 0.036 332.9    5.93   -2.04   -2.56  421.8    68.21
12.79    4.29  -3.88 0.9989E+00
 14  4   1    2 0.281E-01 0.161 0.036 332.6    5.94   -2.02   -2.57  421.8    67.39
12.81    4.33  -3.90 0.9989E+00
 14  4   1    3 0.282E-01 0.161 0.036 332.4    5.95   -1.99   -2.58  421.8    66.59
12.83    4.36  -3.91 0.9989E+00
 14  4   1    4 0.282E-01 0.161 0.036 332.1    5.95   -1.97   -2.58  421.8    65.79
12.85    4.39  -3.92 0.9989E+00
 14  4   1    5 0.283E-01 0.162 0.036 331.9    5.96   -1.94   -2.59  421.8    65.01
12.87    4.43  -3.94 0.9990E+00
 14  4   1    6 0.283E-01 0.162 0.035 331.7    5.97   -1.92   -2.59  421.8    64.24
12.89    4.46  -3.95 0.9990E+00
 14  4   1    7 0.284E-01 0.163 0.035 331.4    5.97   -1.89   -2.60  421.8    63.47
12.91    4.49  -3.96 0.9990E+00
 14  4   1    8 0.284E-01 0.163 0.035 331.2    5.98   -1.87   -2.60  421.8    62.72
12.93    4.52  -3.97 0.9990E+00
 14  4   1    9 0.285E-01 0.163 0.035 331.0    5.99   -1.85   -2.60  421.8    61.98
12.95    4.55  -3.98 0.9990E+00
 14  4   1   10 0.286E-01 0.163 0.035 330.7    6.00   -1.82   -2.61  421.8    61.24
12.97    4.57  -4.00 0.9990E+00
 14  4   1   11 0.286E-01 0.164 0.035 330.5    6.00   -1.80   -2.61  421.8    60.52
12.99    4.60  -4.01 0.9990E+00
 14  4   1   12 0.287E-01 0.164 0.035 330.3    6.01   -1.78   -2.61  421.8    59.80
13.01    4.63  -4.02 0.9990E+00
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 14  4  1   13 0.287E-01 0.164 0.035 330.1    6.02  -1.76   -2.62  421.8    59.10
13.03    4.65  -4.03 0.9991E+00
 14  4  1   14 0.287E-01 0.165 0.035 329.9    6.02  -1.73   -2.62  421.8    58.40
13.05    4.67  -4.04 0.9991E+00
 14  4  1   15 0.288E-01 0.165 0.035 329.7    6.03  -1.71   -2.62  421.8    57.72
13.06    4.70  -4.05 0.9991E+00
 14  4  1   16 0.288E-01 0.165 0.035 329.5    6.04  -1.69   -2.63  421.8    57.04
13.08    4.72  -4.05 0.9991E+00
 14  4  1   17 0.289E-01 0.165 0.034 329.3    6.05  -1.67   -2.63  421.8    56.37
13.10    4.74  -4.06 0.9991E+00
 14  4  1   18 0.289E-01 0.166 0.034 329.1    6.05  -1.65   -2.63  421.8    55.71
13.11    4.76  -4.07 0.9991E+00
 14  4  1   19 0.290E-01 0.166 0.034 328.9    6.06  -1.63   -2.63  421.8    55.06
13.13    4.78  -4.08 0.9991E+00
 14  4  1   20 0.290E-01 0.166 0.034 328.7    6.07  -1.61   -2.63  421.8    54.42
13.14    4.80  -4.09 0.9991E+00
 14  4  1   21 0.291E-01 0.166 0.034 328.6    6.08  -1.59   -2.64  421.8    53.79
13.16    4.82  -4.10 0.9991E+00
 14  4  1   22 0.291E-01 0.167 0.034 328..74 4    6.09  -1.57   -2.64  421.8   53.
16  13.17    4.83  -4.10 0.9992E+00
 14  4  1   23 0.291E-01 0.167 0.034 328.2    6.09  -1.55   -2.64  421.8    52.54
13.19    4.85  -4.11 0.9992E+00
 14  4  1   24 0.292E-01 0.167 0.034 328.1    6.10  -1.53   -2.64  421.8    51.93
13.20    4.87  -4.12 0.9992E+00
 14  4  1   25 0.292E-01 0.167 0.034 327.9    6.11  -1.51   -2.64  421.8    51.33
13.21    4.88  -4.12 0.9992E+00

STILL IN ZONE AFTER     300 STEPS.
  XPOLD =0.178  YPOLD =0.032
  DSTRIB(10, 3) =  1    DSTMAX =1

  1 11  1    1 0.110E-04 0.000 0.140    0.0    6.06  -3.50    0.00  298.2  210.00
-1.07   -5.91    0.00 0.9968E+00
  1 11  1    2 0.110E-04 0.000 0.140    0.0    6.06  -3.50    0.00  298.2  210.00
-1.08   -5.92    0.00 0.9968E+00
  1 11  1    1 0.334E-03 0.002 0.139  360.0    6.02  -3.53    0.00  305.1  210.00
-1.23   -6.11    0.00 0.9968E+00
  1 11  1    2 0.334E-03 0.004 0.138  360.0    6.02  -3.53    0.00  305.1  210.00
-1.38   -6.31    0.00 0.9968E+00
  1 11  1    1 0.530E-03 0.005 0.137    0.0    6.00  -3.55    0.00  309.2  210.00
-1.47   -6.43    0.00 0.9968E+00
  1 11  1    2 0.667E-03 0.006 0.136    0.0    5.98  -3.56    0.00  312.2  210.00
-1.56   -6.55    0.00 0.9968E+00
  1 11  1    1 0.785E-03 0.007 0.136  360.0    5.97  -3.58    0.00  314.7  210.00
-1.61   -6.62    0.00 0.9968E+00
  1 11  1    2 0.904E-03 0.008 0.135  360.0    5.95  -3.59    0.00  317.2  210.00
-1.67   -6.70    0.00 0.9968E+00
  1 11  1    3 0.102E-02 0.009 0.135  360.0    5.94  -3.60    0.00  319.7  210.00
-1.72   -6.77    0.00 0.9968E+00
  1 11  1    4 0.114E-02 0.009 0.135  360.0    5.93  -3.62    0.00  322.2  210.00
-1.77   -6.84    0.00 0.9968E+00
  1 11  1    5 0.126E-02 0.010 0.134  360.0    5.91  -3.63    0.00  324.7  210.00
-1.83   -6.92    0.00 0.9968E+00
  1 11  1    6 0.126E-02 0.010 0.134  360.0    5.91  -3.63    0.00  324.7  210.00
-1.83   -6.92    0.00 0.9968E+00
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  2 11   1     1 0.160E-02 0.012 0.133 360.0   5.87  -3.68   0.00  332.1  210.00
-1.10   -8.74   -3.05 0.9968E+00
  2 11   1     2 0.194E-02 0.014 0.132 360.0   5.84  -3.74  -0.01  339.6  210.00
-0.37   -8.39   -3.08 0.9968E+00
  2 11   1     3 0.228E-02 0.016 0.130 360.0   5.81  -3.79  -0.02  346.8  210.00
 0.35   -8.03   -3.11 0.9968E+00
  2 11   1     4 0.262E-02 0.018 0.129 360.0   5.78  -3.84  -0.04  353.8  210.00
 1.07   -7.67   -3.14 0.9968E+00
  2 11   1     5 0.295E-02 0.020 0.128 360.0   5.76  -3.88  -0.05  360.6  210.00
 1.79   -7.30   -3.17 0.9968E+00
  2 11   1     6 0.297E-02 0.020 0.128 360.0   5.76  -3.88  -0.06  361.0  210.00
 1.83   -7.27   -3.17 0.9968E+00
  3 11   1     1 0.332E-02 0.022 0.126 360.0   5.74  -3.92  -0.07  367.7  210.00
 1.80   -6.64   -3.21 0.9968E+00
  3 11   1     2 0.367E-02 0.024 0.125 360.0   5.72  -3.95  -0.09  374.3  210.00
 1.77   -6.76   -3.24 0.9968E+00
  3 11   1     3 0.402E-02 0.026 0.124 360.0   5.71  -3.97  -0.11  380.9  210.00
 1.74   -6.89   -3.28 0.9968E+00
  3 11   1     4 0.436E-02 0.028 0.122 359.9   5.69  -4.00  -0.13  387.4  210.00
 1.71   -7.02   -3.31 0.9968E+00
  3 11   1     5 0.471E-02 0.030 0.121 359.9   5.67  -4.04  -0.16  393.9  210.00
 1.68   -7.14   -3.35 0.9968E+00
  3 11   1     6 0.472E-02 0.030 0.121 359.9   5.67  -4.04  -0.16  394.1  210.00
 1.68   -7.15   -3.35 0.9968E+00
  4 11   1     1 0.476E-02 0.030 0.121 359.9   5.67  -4.04  -0.16  394.8  210.00
 1.58   -4.22   -3.36 0.9968E+00
  4 11   1     2 0.480E-02 0.030 0.120 359.9   5.67  -4.04  -0.16  395.5  210.00
 1.49   -4.21   -3.36 0.9968E+00
  4 11   1     3 0.484E-02 0.031 0.120 359.9   5.67  -4.04  -0.16  396.2  210.00
 1.39   -4.20   -3.37 0.9968E+00
  4 11   1     4 0.488E-02 0.031 0.120 359.9   5.66  -4.04  -0.17  397.0  210.00
 1.30   -4.18   -3.37 0.9968E+00
  4 11   1     5 0.492E-02 0.031 0.120 359.9   5.66  -4.04  -0.17  397.7  210.00
 1.21   -4.17   -3.37 0.9968E+00
  4 10   1     1 0.523E-02 0.033 0.119 359.9   5.64  -4.05  -0.19  403.5  210.00
-1.26   -4.27   -3.54 0.9968E+00
  4 10   1     2 0.555E-02 0.035 0.117 359.8   5.61  -4.05  -0.21  409.6  210.00
-1.43   -4.37   -3.58 0.9968E+00
  4 10   1     3 0.586E-02 0.036 0.116 359.8   5.57  -4.06  -0.23  415.8  210.00
-1.59   -4.47   -3.61 0.9967E+00
  4 10   1     4 0.617E-02 0.038 0.115 359.8   5.53  -4.07  -0.25  421.8  209.98
-1.75   -4.57   -3.65 0.9967E+00
  4 10   1     5 0.649E-02 0.040 0.114 359.7   5.53  -4.07  -0.25  421.8  208.72
-1.91   -4.67   -3.70 0.9967E+00
  4 10   1     6 0.650E-02 0.040 0.114 359.7   5.53  -4.07  -0.25  421.8  208.65
-1.91   -4.68   -3.70 0.9967E+00
  5 10   1     1 0.686E-02 0.042 0.112 359.7   5.52  -4.08  -0.26  421.8  207.19
-1.99   -7.65   -3.75 0.9967E+00
  5 10   1     2 0.721E-02 0.044 0.111 359.6   5.51  -4.09  -0.27  421.8  205.71
-2.07   -7.34   -3.79 0.9968E+00
  5 10   1     3 0.756E-02 0.046 0.109 359.6   5.51  -4.10  -0.28  421.8  204.25
-2.14   -7.03   -3.84 0.9968E+00
  5 10   1     4 0.790E-02 0.048 0.108 359.5   5.50  -4.10  -0.28  421.8  202.79
-2.22   -6.73   -3.89 0.9968E+00
  5 10   1     5 0.824E-02 0.050 0.106 359.5   5.49  -4.11  -0.29  421.8  201.36
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-2.29   -6.43   -3.94 0.9968E+00
  5 10   1     6 0.832E-02 0.050  0.106  359.5    5.49   -4.11   -0.29   421.8   201.02
-2.30   -6.36   -3.96 0.9969E+00
  6 10   1     1 0.865E-02 0.052  0.105  359.4    5.48   -4.12   -0.30   421.8   199.59
-2.33   -3.47   -5.01 0.9969E+00
  6 10   1     2 0.898E-02 0.054  0.103  359.4    5.47   -4.12   -0.31   421.8   198.15
-2.36   -3.40   -5.08 0.9969E+00
  6 10   1     3 0.931E-02 0.055  0.102  359.3    5.47   -4.13   -0.32   421.8   196.73
-2.39   -3.34   -5.14 0.9969E+00
  6 10   1     4 0.963E-02 0.057  0.101  359.3    5.46   -4.13   -0.33   421.8   195.32
-2.41   -3.28   -5.21 0.9969E+00
  6 10   1     5 0.994E-02 0.059  0.099  359.2    5.45   -4.13   -0.35   421.8   193.92
-2.44   -3.22   -5.28 0.9969E+00
  6 10   1     6 0.101E-01 0.060  0.099  359.2    5.45   -4.13   -0.35   421.8   193.00
-2.46   -3.18   -5.32 0.9970E+00
  7 10   1     1 0.105E-01 0.062  0.097  359.1    5.44   -4.13   -0.37   421.8   191.61
-3.02   -4.78   -6.47 0.9970E+00
  7 10   1     2 0.108E-01 0.063  0.096  359.0    5.43   -4.13   -0.38   421.8   190.19
-3.58   -4.59   -6.56 0.9970E+00
  7 10   1     3 0.111E-01 0.065  0.095  359.0    5.42   -4.14   -0.40   421.8   188.77
-4.13   -4.41   -6.64 0.9970E+00
  7 10   1     4 0.114E-01 0.067  0.094  358.9    5.41   -4.14   -0.41   421.8   187.36
-4.67   -4.23   -6.73 0.9970E+00
  7 10   1     5 0.117E-01 0.068  0.092  358.8    5.40   -4.14   -0.43   421.8   185.94
-5.20   -4.05   -6.82 0.9971E+00
  7 10   1     6 0.119E-01 0.070  0.091  358.7    5.39   -4.14   -0.44   421.8   184.52
-5.72   -3.87   -6.91 0.9971E+00
  7 10   1     7 0.120E-01 0.070  0.091  358.7    5.39   -4.14   -0.45   421.8   184.27
-5.81   -3.84   -6.92 0.9971E+00
  8 10   1     1 0.120E-01 0.070  0.091  358.7    5.39   -4.14   -0.45   421.8   184.09
-5.75   -0.74   -8.09 0.9971E+00
  8 10   1     2 0.121E-01 0.070  0.091  358.7    5.39   -4.14   -0.45   421.8   183.90
-5.68   -0.69   -8.10 0.9971E+00
  8 10   1     3 0.121E-01 0.071  0.091  358.7    5.39   -4.14   -0.45   421.8   183.71
-5.62   -0.64   -8.12 0.9971E+00
  8 10   1     4 0.121E-01 0.071  0.090  358.7    5.38   -4.14   -0.46   421.8   183.52
-5.55   -0.59   -8.13 0.9971E+00
  8 10   1     5 0.122E-01 0.071  0.090  358.7    5.38   -4.14   -0.46   421.8   183.33
-5.49   -0.55   -8.15 0.9971E+00
  8 10   1     6 0.122E-01 0.071  0.090  358.7    5.38   -4.14   -0.46   421.8   183.14
-5.43   -0.50   -8.16 0.9971E+00
  8 10   1     7 0.122E-01 0.071  0.090  358.7    5.38   -4.14   -0.46   421.8   183.04
-5.36   -0.48   -8.17 0.9971E+00
  8  9   1     1 0.125E-01 0.073  0.089  358.6    5.37   -4.13   -0.48   421.8   181.78
 4.32   -1.12   -9.55 0.9971E+00
  8  9   1     2 0.127E-01 0.074  0.088  358.5    5.37   -4.13   -0.51   421.8   180.64
 4.24   -1.75   -9.66 0.9971E+00
  8  9   1     3 0.130E-01 0.075  0.087  358.4    5.37   -4.13   -0.53   421.8   179.50
 4.15   -2.38   -9.77 0.9971E+00
  8  9   1     4 0.132E-01 0.077  0.086  358.4    5.37   -4.13   -0.56   421.8   178.37
 4.06   -3.00   -9.88 0.9972E+00
  8  9   1     5 0.134E-01 0.078  0.085  358.3    5.37   -4.13   -0.58   421.8   177.25
 3.98   -3.61   -9.99 0.9972E+00
  8  9   1     6 0.136E-01 0.079  0.084  358.2    5.37   -4.13   -0.61   421.8   176.14
 3.90   -4.21  -10.10 0.9972E+00
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  8  9  1     7 0.138E-01 0.080 0.083 358.1    5.37  -4.13   -0.63  421.8  175.21
 3.83   -4.71 -10.19 0.9972E+00
  9  9  1     1 0.139E-01 0.081 0.083 358.0    5.37  -4.13   -0.65  421.8  174.64
 3.60   -4.31 -10.25 0.9972E+00
  9  9  1     2 0.141E-01 0.081 0.082 358.0    5.37  -4.13   -0.66  421.8  174.08
 3.37   -3.97 -10.31 0.9972E+00
  9  9  1     3 0.142E-01 0.082 0.082 357.9    5.37  -4.13   -0.67  421.8  173.52
 3.15   -3.64 -10.37 0.9973E+00
  9  9  1     4 0.143E-01 0.082 0.082 357.9    5.37  -4.12   -0.69  421.8  172.96
 2.93   -3.31 -10.43 0.9973E+00
  9  9  1     5 0.144E-01 0.083 0.081 357.8    5.37  -4.12   -0.70  421.8  172.40
 2.70   -2.98 -10.49 0.9973E+00
  9  9  1     6 0.145E-01 0.084 0.081 357.8    5.37  -4.12   -0.72  421.8  171.84
 2.48   -2.65 -10.55 0.9973E+00
  9  9  1     7 0.146E-01 0.084 0.080 357.7    5.37  -4.12   -0.73  421.8  171.28
 2.26   -2.33 -10.60 0.9973E+00
  9  9  1     8 0.147E-01 0.085 0.080 357.7    5.37  -4.12   -0.74  421.8  171.09
 2.05   -2.22 -10.62 0.9973E+00
  9  8  1     1 0.148E-01 0.085 0.079 357.6    5.37  -4.12   -0.75  421.8  170.42
 8.37   -2.38 -10.38 0.9973E+00
  9  8  1     2 0.149E-01 0.086 0.079 357.6    5.37  -4.11   -0.77  421.8  169.75
 8.50   -2.53 -10.45 0.9973E+00
  9  8  1     3 0.150E-01 0.087 0.078 357.5    5.37  -4.11   -0.78  421.8  169.09
 8.63   -2.69 -10.52 0.9973E+00
  9  8  1     4 0.152E-01 0.088 0.078 357.4    5.37  -4.11   -0.80  421.8  168.43
 8.76   -2.84 -10.59 0.9973E+00
  9  8  1     5 0.153E-01 0.088 0.077 357.4    5.37  -4.11   -0.82  421.8  167.77
 8.89   -2.99 -10.66 0.9973E+00
  9  8  1     6 0.154E-01 0.089 0.077 357.3    5.37  -4.10   -0.83  421.8  167.11
 9.02   -3.14 -10.73 0.9974E+00
  9  8  1     7 0.155E-01 0.090 0.076 357.2    5.37  -4.10   -0.85  421.8  166.46
 9.15   -3.29 -10.80 0.9974E+00
  9  8  1     8 0.156E-01 0.090 0.076 357.1    5.37  -4.10   -0.86  421.8  165.98
 9.24   -3.40 -10.85 0.9974E+00
 10  8  1     1 0.158E-01 0.091 0.075 357.0    5.37  -4.09   -0.89  421.8  164.99
 9.61   -1.85 -10.96 0.9974E+00
 10  8  1     2 0.160E-01 0.092 0.075 356.9    5.37  -4.09   -0.91  421.8  164.00
 9.97   -1.46 -11.07 0.9974E+00
 10  8  1     3 0.162E-01 0.093 0.074 356.8    5.38  -4.08   -0.93  421.8  163.02
10.33   -1.08 -11.18 0.9974E+00
 10  8  1     4 0.163E-01 0.094 0.073 356.7    5.38  -4.08   -0.96  421.8  162.03
10.69   -0.70 -11.29 0.9974E+00
 10  8  1     5 0.165E-01 0.095 0.072 356.5    5.38  -4.07   -0.98  421.8  161.05
11.04   -0.32 -11.40 0.9974E+00
 10  8  1     6 0.167E-01 0.096 0.072 356.4    5.38  -4.06   -1.01  421.8  160.07
11.39    0.04 -11.51 0.9975E+00
 10  8  1     7 0.169E-01 0.097 0.071 356.3    5.38  -4.05   -1.03  421.8  159.09
11.74    0.41 -11.63 0.9975E+00
 10  8  1     8 0.170E-01 0.098 0.070 356.1    5.39  -4.04   -1.06  421.8  158.11
12.08    0.77 -11.74 0.9975E+00
 10  8  1     9 0.171E-01 0.098 0.070 356.1    5.39  -4.04   -1.06  421.8  157.70
12.41    0.91 -11.79 0.9975E+00
 10  7  1     1 0.171E-01 0.099 0.070 356.0    5.39  -4.04   -1.07  421.8  157.51
17.84    0.93 -10.23 0.9975E+00
 10  7  1     2 0.172E-01 0.099 0.070 356.0    5.39  -4.03   -1.07  421.8  157.30
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17.84    0.94 -10.25 0.9975E+00
 10  7   1     3 0.172E-01 0.099 0.070 356.0   5.39  -4.03  -1.08  421.8  157.10
17.84    0.95 -10.27 0.9975E+00
 10  7   1     4 0.172E-01 0.099 0.069 355.9   5.39  -4.03  -1.08  421.8  156.90
17.84    0.97 -10.29 0.9975E+00
 10  7   1     5 0.173E-01 0.099 0.069 355.9   5.39  -4.03  -1.08  421.8  156.70
17.85    0.98 -10.31 0.9975E+00
 10  7   1     6 0.173E-01 0.099 0.069 355.9   5.40  -4.02  -1.09  421.8  156.49
17.85    0.99 -10.33 0.9975E+00
 10  7   1     7 0.173E-01 0.100 0.069 355.9   5.40  -4.02  -1.09  421.8  156.29
17.85    1.00 -10.35 0.9975E+00
 10  7   1     8 0.174E-01 0.100 0.069 355.8   5.40  -4.02  -1.09  421.8  156.09
17.85    1.02 -10.37 0.9975E+00
 10  7   1     9 0.174E-01 0.100 0.069 355.8   5.40  -4.02  -1.10  421.8  155.90
17.85    1.03 -10.39 0.9975E+00
 11  7   1     1 0.176E-01 0.101 0.068 355.6   5.41  -4.00  -1.12  421.8  154.35
17.67    0.14  -9.58 0.9975E+00
 11  7   1     2 0.179E-01 0.103 0.067 355.3   5.43  -3.98  -1.15  421.8  152.84
17.48    0.24  -9.71 0.9976E+00
 11  7   1     3 0.181E-01 0.104 0.066 355.1   5.44  -3.97  -1.17  421.8  151.35
17.30    0.34  -9.85 0.9976E+00
 11  7   1     4 0.183E-01 0.105 0.065 354.9   5.45  -3.96  -1.19  421.8  149.88
17.13    0.44  -9.99 0.9976E+00
 11  7   1     5 0.186E-01 0.106 0.064 354.7   5.46  -3.94  -1.22  421.8  148.42
16.95    0.54 -10.13 0.9976E+00
 11  7   1     6 0.188E-01 0.108 0.063 354.4   5.47  -3.93  -1.24  421.8  146.99
16.78    0.63 -10.26 0.9977E+00
 11  7   1     7 0.190E-01 0.109 0.062 354.2   5.49  -3.91  -1.27  421.8  145.57
16.61    0.72 -10.40 0.9977E+00
 11  7   1     8 0.192E-01 0.110 0.062 353.9   5.50  -3.90  -1.30  421.8  144.17
16.45    0.81 -10.54 0.9977E+00
 11  7   1     9 0.194E-01 0.111 0.061 353.7   5.51  -3.89  -1.33  421.8  142.79
16.28    0.90 -10.68 0.9977E+00
 11  7   1    10 0.196E-01 0.112 0.060 353.4   5.52  -3.87  -1.36  421.8  141.43
16.12    0.98 -10.82 0.9978E+00
 11  7   1    11 0.196E-01 0.113 0.060 353.4   5.52  -3.87  -1.36  421.8  141.34
15.97    0.99 -10.83 0.9978E+00
 11  6   1     1 0.197E-01 0.114 0.060 353.3   5.52  -3.86  -1.38  421.8  140.56
15.02    1.15  -9.23 0.9978E+00
 11  6   1     2 0.198E-01 0.114 0.059 353.1   5.53  -3.86  -1.39  421.8  139.81
14.98    1.32  -9.30 0.9978E+00
 11  6   1     3 0.200E-01 0.115 0.059 353.0   5.53  -3.85  -1.41  421.8  139.07
14.95    1.48  -9.37 0.9978E+00
 11  6   1     4 0.201E-01 0.116 0.058 352.8   5.54  -3.84  -1.42  421.8  138.32
14.91    1.63  -9.43 0.9978E+00
 11  6   1     5 0.202E-01 0.116 0.058 352.7   5.54  -3.83  -1.44  421.8  137.58
14.88    1.79  -9.50 0.9978E+00
 11  6   1     6 0.203E-01 0.117 0.057 352.5   5.55  -3.82  -1.46  421.8  136.85
14.85    1.95  -9.57 0.9979E+00
 11  6   1     7 0.204E-01 0.117 0.057 352.4   5.55  -3.81  -1.47  421.8  136.12
14.82    2.10  -9.63 0.9979E+00
 11  6   1     8 0.205E-01 0.118 0.057 352.2   5.55  -3.80  -1.49  421.8  135.39
14.78    2.25  -9.70 0.9979E+00
 11  6   1     9 0.206E-01 0.119 0.056 352.1   5.56  -3.79  -1.51  421.8  134.66
14.75    2.40  -9.77 0.9979E+00
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 11  6  1   10 0.207E-01 0.119 0.056 351.9   5.56  -3.78  -1.52  421.8  133.94
14.72    2.54   -9.83 0.9979E+00
 11  6  1   11 0.208E-01 0.120 0.056 351.8   5.57  -3.77  -1.54  421.8  133.23
14.69    2.69   -9.90 0.9979E+00
 11  6  1   12 0.208E-01 0.120 0.055 351.7   5.57  -3.76  -1.55  421.8  132.78
14.67    2.78   -9.94 0.9979E+00
 12  6  1    1 0.210E-01 0.121 0.055 351.5   5.57  -3.75  -1.57  421.8  131.96
14.69    3.52   -8.01 0.9979E+00
 12  6  1    2 0.211E-01 0.121 0.054 351.3   5.58  -3.73  -1.59  421.8  131.15
14.70    3.60   -8.08 0.9979E+00
 12  6  1    3 0.212E-01 0.122 0.054 351.1   5.58  -3.72  -1.61  421.8  130.34
14.72    3.67   -8.14 0.9980E+00
 12  6  1    4 0.213E-01 0.122 0.054 350.9   5.59  -3.70  -1.62  421.8  129.54
14.73    3.75   -8.20 0.9980E+00
 12  6  1    5 0.214E-01 0.123 0.053 350.7   5.59  -3.69  -1.64  421.8  128.75
14.75    3.83   -8.26 0.9980E+00
 12  6  1    6 0.215E-01 0.124 0.053 350.5   5.60  -3.67  -1.66  421.8  127.96
14.76    3.90   -8.32 0.9980E+00
 12  6  1    7 0.216E-01 0.124 0.052 350.4   5.60  -3.65  -1.67  421.8  127.18
14.77    3.98   -8.38 0.9980E+00
 12  6  1    8 0.217E-01 0.125 0.052 350.2   5.61  -3.64  -1.69  421.8  126.40
14.79    4.05   -8.44 0.9980E+00
 12  6  1    9 0.218E-01 0.125 0.052 350.0   5.61  -3.62  -1.71  421.8  125.62
14.80    4.12   -8.51 0.9980E+00
 12  6  1   10 0.219E-01 0.126 0.051 349.8   5.62  -3.60  -1.72  421.8  124.85
14.82    4.19   -8.57 0.9980E+00
 12  6  1   11 0.220E-01 0.127 0.051 349.6   5.62  -3.59  -1.74  421.8  124.09
14.83    4.26   -8.63 0.9981E+00
 12  6  1   12 0.221E-01 0.127 0.051 349.4   5.63  -3.57  -1.75  421.8  123.33
14.84    4.33   -8.69 0.9981E+00
 12  6  1   13 0.222E-01 0.128 0.050 349.2   5.63  -3.55  -1.77  421.8  122.58
14.86    4.39   -8.75 0.9981E+00
 12  6  1   14 0.223E-01 0.128 0.050 349.0   5.64  -3.54  -1.78  421.8  121.92
14.87    4.45   -8.80 0.9981E+00
 12  5  1    1 0.224E-01 0.129 0.050 348.7   5.64  -3.51  -1.81  421.8  120.79
12.80    4.45   -5.45 0.9981E+00
 12  5  1    2 0.226E-01 0.130 0.049 348.5   5.65  -3.49  -1.83  421.8  119.72
12.85    4.45   -5.51 0.9981E+00
 12  5  1    3 0.227E-01 0.131 0.049 348.2   5.66  -3.47  -1.84  421.8  118.66
12.90    4.45   -5.56 0.9981E+00
 12  5  1    4 0.228E-01 0.131 0.048 347.9   5.66  -3.44  -1.86  421.8  117.61
12.94    4.45   -5.62 0.9982E+00
 12  5  1    5 0.230E-01 0.132 0.048 347.6   5.67  -3.42  -1.88  421.8  116.57
12.98    4.45   -5.67 0.9982E+00
 12  5  1    6 0.231E-01 0.133 0.047 347.3   5.67  -3.40  -1.90  421.8  115.55
13.03    4.45   -5.72 0.9982E+00
 12  5  1    7 0.232E-01 0.133 0.047 347.0   5.68  -3.37  -1.92  421.8  114.53
13.07    4.45   -5.78 0.9982E+00
 12  5  1    8 0.234E-01 0.134 0.046 346.7   5.68  -3.35  -1.94  421.8  113.52
13.11    4.45   -5.83 0.9982E+00
 12  5  1    9 0.235E-01 0.135 0.046 346.4   5.69  -3.33  -1.96  421.8  112.53
13.15    4.45   -5.88 0.9982E+00
 12  5  1   10 0.236E-01 0.136 0.046 346.1   5.70  -3.31  -1.98  421.8  111.54
13.19    4.45   -5.93 0.9982E+00
 12  5  1   11 0.237E-01 0.136 0.045 345.8   5.70  -3.28  -2.00  421.8  110.56
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13.23    4.45   -5.98 0.9983E+00
 12  5   1   12 0.238E-01 0.137 0.045 345.5   5.71  -3.26  -2.02  421.8  109.60
13.27    4.45   -6.03 0.9983E+00
 12  5   1   13 0.239E-01 0.138 0.044 345.2   5.71  -3.23  -2.03  421.8  108.64
13.31    4.45   -6.08 0.9983E+00
 12  5   1   14 0.241E-01 0.138 0.044 344.9   5.72  -3.21  -2.05  421.8  107.69
13.35    4.45   -6.13 0.9983E+00
 12  5   1   15 0.242E-01 0.139 0.044 344.7   5.72  -3.18  -2.07  421.8  106.75
13.39    4.45   -6.18 0.9983E+00
 12  5   1   16 0.243E-01 0.139 0.043 344.4   5.73  -3.16  -2.09  421.8  105.83
13.42    4.45   -6.23 0.9983E+00
 12  5   1   17 0.244E-01 0.140 0.043 344.1   5.73  -3.14  -2.11  421.8  105.00
13.46    4.45   -6.28 0.9983E+00
 13  5   1    1 0.244E-01 0.140 0.043 344.0   5.74  -3.12  -2.12  421.8  104.58
13.42    6.15   -5.25 0.9984E+00
 13  5   1    2 0.245E-01 0.141 0.043 343.8   5.74  -3.11  -2.12  421.8  104.16
13.39    6.17   -5.27 0.9984E+00
 13  5   1    3 0.245E-01 0.141 0.043 343.7   5.74  -3.10  -2.13  421.8  103.74
13.35    6.20   -5.29 0.9984E+00
 13  5   1    4 0.246E-01 0.141 0.042 343.6   5.74  -3.08  -2.14  421.8  103.32
13.32    6.22   -5.30 0.9984E+00
 13  5   1    5 0.246E-01 0.141 0.042 343.4   5.75  -3.07  -2.15  421.8  102.90
13.28    6.24   -5.32 0.9984E+00
 13  5   1    6 0.247E-01 0.142 0.042 343.3   5.75  -3.06  -2.15  421.8  102.49
13.25    6.26   -5.34 0.9984E+00
 13  5   1    7 0.247E-01 0.142 0.042 343.1   5.75  -3.05  -2.16  421.8  102.08
13.21    6.29   -5.36 0.9984E+00
 13  5   1    8 0.247E-01 0.142 0.042 343.0   5.75  -3.03  -2.17  421.8  101.67
13.18    6.31   -5.37 0.9984E+00
 13  5   1    9 0.248E-01 0.142 0.042 342.9   5.76  -3.02  -2.17  421.8  101.26
13.14    6.33   -5.39 0.9984E+00
 13  5   1   10 0.248E-01 0.143 0.042 342.7   5.76  -3.01  -2.18  421.8  100.85
13.11    6.35   -5.41 0.9984E+00
 13  5   1   11 0.249E-01 0.143 0.041 342.6   5.76  -2.99  -2.19  421.8  100.45
13.08    6.38   -5.43 0.9984E+00
 13  5   1   12 0.249E-01 0.143 0.041 342.5   5.76  -2.98  -2.19  421.8  100.04
13.05    6.40   -5.44 0.9984E+00
 13  5   1   13 0.250E-01 0.143 0.041 342.3   5.77  -2.97  -2.20  421.8   99.64
13.01    6.42   -5.46 0.9984E+00
 13  5   1   14 0.250E-01 0.144 0.041 342.2   5.77  -2.96  -2.21  421.8   99.24
12.98    6.44   -5.48 0.9984E+00
 13  5   1   15 0.251E-01 0.144 0.041 342.1   5.77  -2.94  -2.21  421.8   98.85
12.95    6.46   -5.50 0.9984E+00
 13  5   1   16 0.251E-01 0.144 0.041 342.0   5.77  -2.93  -2.22  421.8   98.45
12.92    6.48   -5.51 0.9984E+00
 13  5   1   17 0.251E-01 0.144 0.041 341.8   5.78  -2.92  -2.23  421.8   98.06
12.88    6.50   -5.53 0.9985E+00
 13  5   1   18 0.252E-01 0.145 0.041 341.7   5.78  -2.90  -2.23  421.8   97.67
12.85    6.52   -5.55 0.9985E+00
 13  5   1   19 0.252E-01 0.145 0.040 341.6   5.78  -2.89  -2.24  421.8   97.28
12.82    6.54   -5.56 0.9985E+00
 13  5   1   20 0.253E-01 0.145 0.040 341.4   5.78  -2.88  -2.25  421.8   96.89
12.79    6.56   -5.58 0.9985E+00
 13  5   1   21 0.253E-01 0.145 0.040 341.3   5.78  -2.87  -2.25  421.8   96.51
12.76    6.58   -5.60 0.9985E+00
```

```
 13  5  1   22 0.253E-01 0.146 0.040 341.2   5.79  -2.86  -2.26  421.8   96.12
12.73   6.59  -5.61 0.9985E+00
 13  5  1   23 0.254E-01 0.146 0.040 341.1   5.79  -2.85  -2.26  421.8   95.82
12.70   6.61  -5.62 0.9985E+00
 13  4  1    1 0.255E-01 0.146 0.040 340.7   5.79  -2.82  -2.28  421.8   94.79
14.17   6.54  -4.41 0.9985E+00
 13  4  1    2 0.256E-01 0.147 0.039 340.4   5.80  -2.78  -2.29  421.8   93.77
14.09   6.47  -4.44 0.9985E+00
 13  4  1    3 0.257E-01 0.148 0.039 340.1   5.81  -2.75  -2.31  421.8   92.76
14.01   6.40  -4.47 0.9985E+00
 13  4  1    4 0.258E-01 0.148 0.039 339.8   5.81  -2.72  -2.32  421.8   91.76
13.93   6.34  -4.50 0.9985E+00
 13  4  1    5 0.259E-01 0.149 0.039 339.4   5.82  -2.69  -2.34  421.8   90.78
13.86   6.28  -4.53 0.9986E+00
 13  4  1    6 0.260E-01 0.149 0.038 339.1   5.83  -2.66  -2.35  421.8   89.81
13.78   6.22  -4.56 0.9986E+00
 13  4  1    7 0.260E-01 0.150 0.038 338.8   5.83  -2.63  -2.36  421.8   88.86
13.71   6.16  -4.59 0.9986E+00
 13  4  1    8 0.261E-01 0.150 0.038 338.5   5.84  -2.60  -2.37  421.8   87.92
13.64   6.10  -4.61 0.9986E+00
 13  4  1    9 0.262E-01 0.151 0.038 338.2   5.85  -2.57  -2.39  421.8   86.99
13.57   6.05  -4.64 0.9986E+00
 13  4  1   10 0.263E-01 0.151 0.037 337.9   5.85  -2.54  -2.40  421.8   86.08
13.51   6.00  -4.67 0.9986E+00
 13  4  1   11 0.264E-01 0.152 0.037 337.6   5.86  -2.51  -2.41  421.8   85.18
13.44   5.95  -4.69 0.9986E+00
 13  4  1   12 0.265E-01 0.152 0.037 337.3   5.86  -2.48  -2.42  421.8   84.29
13.38   5.90  -4.72 0.9987E+00
 13  4  1   13 0.265E-01 0.153 0.037 337.0   5.87  -2.45  -2.43  421.8   83.41
13.31   5.85  -4.74 0.9987E+00
 13  4  1   14 0.266E-01 0.153 0.037 336.7   5.88  -2.42  -2.44  421.8   82.54
13.25   5.80  -4.77 0.9987E+00
 13  4  1   15 0.267E-01 0.154 0.037 336.4   5.88  -2.39  -2.45  421.8   81.69
13.19   5.76  -4.79 0.9987E+00
 13  4  1   16 0.268E-01 0.154 0.036 336.1   5.89  -2.37  -2.46  421.8   80.85
13.13   5.72  -4.82 0.9987E+00
 13  4  1   17 0.268E-01 0.154 0.036 335.8   5.89  -2.34  -2.47  421.8   80.01
13.07   5.67  -4.84 0.9987E+00
 13  4  1   18 0.269E-01 0.155 0.036 335.6   5.90  -2.31  -2.48  421.8   79.19
13.01   5.63  -4.86 0.9987E+00
 13  4  1   19 0.270E-01 0.155 0.036 335.3   5.90  -2.29  -2.49  421.8   78.38
12.96   5.59  -4.88 0.9987E+00
 13  4  1   20 0.271E-01 0.156 0.036 335.0   5.91  -2.26  -2.50  421.8   77.58
12.90   5.56  -4.90 0.9988E+00
 13  4  1   21 0.271E-01 0.156 0.036 334.8   5.91  -2.24  -2.51  421.8   76.79
12.85   5.52  -4.93 0.9988E+00
 13  4  1   22 0.272E-01 0.156 0.035 334.5   5.92  -2.21  -2.52  421.8   76.02
12.80   5.48  -4.95 0.9988E+00
 13  4  1   23 0.273E-01 0.157 0.035 334.2   5.92  -2.19  -2.53  421.8   75.25
12.74   5.45  -4.97 0.9988E+00
 13  4  1   24 0.273E-01 0.157 0.035 334.0   5.93  -2.16  -2.53  421.8   74.49
12.69   5.42  -4.99 0.9988E+00
 13  4  1   25 0.274E-01 0.158 0.035 333.7   5.93  -2.14  -2.54  421.8   73.74
12.64   5.38  -5.00 0.9988E+00
 14  4  1    1 0.278E-01 0.160 0.034 331.8   5.97  -1.95  -2.61  421.8   67.95
```

```
12.30    6.93   -4.11 0.9989E+00
 14  4  1     2 0.279E-01 0.161 0.034 331.6    5.98  -1.93  -2.62  421.8   67.37
12.30    6.96   -4.12 0.9989E+00
 14  4  1     3 0.279E-01 0.161 0.034 331.4    5.98  -1.90  -2.62  421.8   66.79
12.29    6.99   -4.13 0.9989E+00
 14  4  1     4 0.280E-01 0.161 0.034 331.2    5.98  -1.88  -2.63  421.8   66.23
12.29    7.02   -4.14 0.9989E+00
 14  4  1     5 0.280E-01 0.161 0.034 331.0    5.99  -1.86  -2.63  421.8   65.66
12.29    7.05   -4.15 0.9990E+00
 14  4  1     6 0.280E-01 0.162 0.034 330.8    5.99  -1.84  -2.63  421.8   65.11
12.28    7.08   -4.16 0.9990E+00
 14  4  1     7 0.281E-01 0.162 0.034 330.6    6.00  -1.82  -2.64  421.8   64.55
12.28    7.11   -4.17 0.9990E+00
 14  4  1     8 0.281E-01 0.162 0.033 330.5    6.00  -1.79  -2.64  421.8   64.01
12.27    7.14   -4.18 0.9990E+00
 14  4  1     9 0.282E-01 0.162 0.033 330.3    6.00  -1.77  -2.64  421.8   63.47
12.27    7.16   -4.19 0.9990E+00
 14  4  1    10 0.282E-01 0.162 0.033 330.1    6.01  -1.75  -2.64  421.8   62.93
12.27    7.19   -4.20 0.9990E+00
 14  4  1    11 0.282E-01 0.163 0.033 329.9    6.01  -1.73  -2.65  421.8   62.40
12.26    7.21   -4.21 0.9990E+00
 14  4  1    12 0.283E-01 0.163 0.033 329.8    6.01  -1.71  -2.65  421.8   61.88
12.26    7.24   -4.22 0.9990E+00
 14  4  1    13 0.283E-01 0.163 0.033 329.6    6.02  -1.69  -2.65  421.8   61.36
12.26    7.26   -4.22 0.9990E+00
 14  4  1    14 0.283E-01 0.163 0.033 329.4    6.02  -1.67  -2.65  421.8   60.84
12.25    7.28   -4.23 0.9990E+00
 14  4  1    15 0.284E-01 0.164 0.033 329.3    6.02  -1.65  -2.66  421.8   60.33
12.25    7.30   -4.24 0.9990E+00
 14  4  1    16 0.284E-01 0.164 0.033 329.1    6.03  -1.63  -2.66  421.8   59.82
12.25    7.33   -4.25 0.9990E+00
 14  4  1    17 0.285E-01 0.164 0.033 329.0    6.03  -1.61  -2.66  421.8   59.32
12.24    7.35   -4.25 0.9991E+00
 14  4  1    18 0.285E-01 0.164 0.033 328.8    6.03  -1.59  -2.66  421.8   58.83
12.24    7.37   -4.26 0.9991E+00
 14  4  1    19 0.285E-01 0.164 0.033 328.7    6.04  -1.57  -2.66  421.8   58.34
12.24    7.39   -4.27 0.9991E+00
 14  4  1    20 0.286E-01 0.165 0.033 328.5    6.04  -1.55  -2.67  421.8   57.85
12.24    7.40   -4.27 0.9991E+00
 14  4  1    21 0.286E-01 0.165 0.033 328.4    6.04  -1.53  -2.67  421.8   57.37
12.23    7.42   -4.28 0.9991E+00
 14  4  1    22 0.286E-01 0.165 0.033 328.2    6.05  -1.51  -2.67  421.8   56.89
12.23    7.44   -4.29 0.9991E+00
 14  4  1    23 0.286E-01 0.165 0.033 328.1    6.05  -1.49  -2.67  421.8   56.42
12.23    7.46   -4.29 0.9991E+00
 14  4  1    24 0.287E-01 0.165 0.033 327.9    6.05  -1.47  -2.67  421.8   55.95
12.22    7.47   -4.30 0.9991E+00
 14  4  1    25 0.287E-01 0.165 0.033 327.8    6.06  -1.45  -2.67  421.8   55.49
12.22    7.49   -4.30 0.9991E+00

STILL IN ZONE AFTER      300 STEPS.
  XPOLD =0.177  YPOLD =0.031
  DSTRIB(10, 3) =  2   DSTMAX =     2

  1 11  1     1 0.110E-04 0.000 0.140    0.0    6.06  -3.50    0.00  298.2  210.00
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APPENDIX E

PROGRAM LISTING

INTERACTIVE INPUT GENERATION CODE

```
\SUSAN\CHANGE\CHDAT.FOR
C
C                             PROGRAM CHANGE3
C          (A PROGRAM TO CHANGE BOTH 2-D AND 3-D INPUT FILES)
C
C      Written by Susan Robinson  12/85
C
C       PURPOSE :
C           To interactively modify data files for use in
C           the 2 and 3 dimensional droplet injection codes.
C
C       The files to be modified are:
C           for 2D          - DROPCIN.DAT
C                           - INJECT.INP
C                           - DROP.INP
C           for 3D          - DROP3D.DAT
C
      CHARACTER*2 ACHAR,BCHAR,CCHAR,DCHAR,ECHAR,FCHAR
      LOGICAL*1 CASE1,INCASE(40)
      REAL NOZDIA, NSTEP,LHELIQ,MDOTIN,MDOTXP,MDOTYP
      REAL R,XL,TEMP
      INTEGER CHANGE1,CHANGE2,CHANGE3,INPTYP(6),TIMAX
      REAL XPOLD(20),YPOLD(20),UPOLD(26),VPOLD(21),DINIT(20),LOD(20)
      COMMON/OUTPUT/
     1  NINCIN,CASE1(45),IX,IY,R(5),XL(10),MDOTIN,FCO2,FH2O,FN2,FO2,
     2  UBDY(11,5),VBDY(10,6),TEMP(10,5),ID,
     3  SIGMAX,UMAX
C
C
      OPEN (UNIT=6,FILE='CON')
      OPEN (UNIT=5,FILE='CON')
      WRITE(6,10)
 10   FORMAT(5X,'THIS IS AN INTERACTIVE INPUT PROGRAM FOR THE DROPLET IN
     1JECTION MODEL.')
      WRITE(6,20)
 20   FORMAT(5X,'WHICH VERSION DO YOU DESIRE TO RUN, 2- OR 3-D?',/5X,
     1'TYPE  2  FOR TWO DIMENSIONAL OR  3  FOR THREE DIMENSIONAL.  '/5X)
 35   READ (5,36) ACHAR
 36   FORMAT(A2)
      IF (ACHAR.EQ.'3') CALL THREED
      IF (ACHAR.EQ.'3') GO TO 900
      IF (ACHAR.EQ.'2') GO TO 100
      WRITE(6,40)
 40   FORMAT(1X,'PLEASE TYPE  2  OR  3  ')
      GO TO 35
C
C     TWO DIMENSIONAL INPUT - FILES FOR DROP2D.FOR
C
 100  WRITE (6,110)
 110  FORMAT (1X,'THERE IS ONE INPUT FILE WITH THREE PARTS.',
     1' EACH WILL BE EDITED SEPARATELY.'/)
C
C        EDIT FILE DROP3D.DAT
C
      OPEN (2,STATUS='OLD',FILE='DROP2D.DAT')
      WRITE (6,120)
 120  FORMAT(1X,'THE FIRST PART CONTAINS ALL DATA',
     1' TO SPECIFY THE FURNACE CONDITIONS.'/)
C
      ID = 2
      READ (ID,125) CASE1
 125  FORMAT (45A1)
      READ (ID,*) IX,IY
      READ (ID,*) (XL(I), I=1,IX)
      READ (ID,*) (R(J),J=1,IY)
      READ (ID,*) MDOTIN
      READ (ID,*) FCO2,FH2O,FN2,FO2
C
      IXPLUS = IX + 1
      IYPLUS = IY + 1
      DO 126 I = 1,IXPLUS
      READ (ID,*) (UBDY(I,J), J=1,IY)
 126  CONTINUE
      DO 135 J=1,IYPLUS
      READ(ID,*) (VBDY(I,J), I=1,IX)
 135  CONTINUE
C
      DO 160 I=1,IX
      READ(ID,*) (TEMP(I,J), J=1,IY)
 160  CONTINUE
C
C
C     WRITE THE DATA FILE TO THE TERMINAL
C
 166  WRITE (6,172) CASE1
 172  FORMAT (/2X,'THE INFORMATION FOR THE CURRENT CASE IS GIVEN BELOW',
     1//6X,'1  CASE NAME                     ',45A1)
      WRITE(6,180) IX,IY
 180  FORMAT(6X,'2  THE NUMBER OF AXIAL ZONES  -  ',I2/6X,'3  THE NUMBER
     1 OF RADIAL ZONES  -  ',I2)
C
      WRITE (6,200)
 200  FORMAT (6X,'4  THE RADIAL POSITIONS OF EACH ZONE BOUNDARY ')
C
      WRITE (6,210)
 210  FORMAT(6X,'5  THE AXIAL LOCATIONS OF EACH OF THE ZONE BOUNDARIES')
C
      WRITE (6,220)
 220  FORMAT (6X,'6  THE TOTAL MASS FLOW RATE ' )
      WRITE (6,230)
 230  FORMAT (6X,'7  INPUT VELOCITIES AT ZONE BOUNDARIES')
      WRITE (6,270)
 270  FORMAT (6X,'8  MASS FRACTIONS (WET) OF CO2,H2O,N2,O2  ')
C
      WRITE (6,290)
 290  FORMAT ( 6X,'9  GAS TEMPERATURES ')
C
C     OPTION TO CHANGE DATA
C
  305 WRITE (6,310)
  310 FORMAT(/2X,'PLEASE TYPE THE ITEM NUMBER OF THE VALUE TO BE CHANGED
     1.'/2X,'IF NO CHANGES ARE TO BE MADE TYPE  10 .')
C
      READ (5,*,ERR=435) CHANGE1
      GO TO (315,325,335,345,355,365,375,403,410,600), CHANGE1
C
C
  315 WRITE (6,320) CASE1
  320 FORMAT (/2X,'CURRENT CASE TITLE IS  ',45A1/2X,'ENTER NEW TITLE  ')
      READ (5,321,ERR=445)  CASE1
  321 FORMAT (45A1)
      GO TO 166
C
  325 WRITE(6,330) IX
  330 FORMAT(/2X,'CURRENT NUMBER OF AXIAL ZONES IS ',I2,
     1',  ENTER NEW VALUE    ')
      READ(5,*,ERR=435) IX
      GO TO 166
C
  335 WRITE(6,340) IY
  340 FORMAT(/2X,'CURRENT NUMBER OF RADIAL ZONES IS ',I2,
     1'.  ENTER NEW VALUE  ')
      READ (5,*,ERR=435) IY
      GO TO 166
C
  345 WRITE(6,350) (J,R(J), J=1,IY)
  350 FORMAT(/2X,'THE CURRENT VALUES OF R ARE'/(5X,I2,5X,F8.5))
      WRITE(6,352)
  352 FORMAT(2X,'ARE ANY OF THESE VALUES TO BE CHANGED?  Y OR N  ')
      READ(5,402,ERR=441) FCHAR
      IF (FCHAR.EQ.'N'.OR.FCHAR.EQ.'n') GO TO 166
      IF (FCHAR.NE.'Y'.OR.FCHAR.NE.'y') GO TO 441
      WRITE (6,351)
  351 FORMAT (2X,'ENTER THE ZONE NUMBER AND RADIAL POSITION  ')
      READ(5,*,ERR=443) I,R(I)
      GO TO 345
C
  355 WRITE(6,360) (J,XL(J),J=1,IX)
  360 FORMAT(/2X,'THE CURRENT VALUES OF AXIAL POSITION ARE'/
     1(5X,I2,5X,F8.5))
      WRITE (6,352,ERR=441)
      READ(5,402,ERR=441) FCHAR
      IF (FCHAR.EQ.'N'.OR.FCHAR.EQ.'n') GO TO 166
      IF (FCHAR.NE.'Y'.OR.FCHAR.NE.'y') GO TO 441
      WRITE(6,361)
  361 FORMAT(2X,'ENTER THE NEW ZONE NUMBER AND AXIAL POSITION   ')
      READ(5,*,ERR=445) I,XL(I)
      GO TO 355
C
  365 WRITE(6,370) MDOTIN
  370 FORMAT(/2X,'THE CURRENT MASS FLOW RATE IS',F9.4,' KG/SEC.'/2X,
     1'ENTER NEW VALUE   ')
      READ(5,*,ERR=437) MDOTIN
      GO TO 166
C
```

```
 375  WRITE(6,380)
 380  FORMAT(/2X,'WHICH OF THE FOLLOWING DO YOU WISH TO ',
     1'CHANGE?'//2X,'1 - X DIRECTION MASS FLOW RATES',/2X,
     2'2 - Y DIRECTION VELOCITIES'
     3//2X, 'TYPE 3 IF NO CHANGES ARE TO BE MADE   ')
      READ(5,*,ERR=435)  CHANGE2
      GO TO (381,391,398), CHANGE2
C
 381  IXPLUS = IX + 1
      WRITE(6,382) (J, J=1,IY)
 382  FORMAT (2X,'THE CURRENT VALUES OF AXIAL VELOCITY AT THE ZONE',
     1' BOUNDARIES ARE'/2X,'I',4X,10(2X,'J =',I2,:,4X))
      DO 384 I = 1,IXPLUS
      WRITE (6,383) I,(UBDY(I,J),J=1,IY)
 383  FORMAT(2X,I2,10(6X,F7.3))
 384  CONTINUE
      WRITE (6,428)
      READ(5,402,ERR=443) FCHAR
      IF (FCHAR.EQ.'R'.OR.FCHAR.EQ.'r') GO TO 375
      IF (FCHAR.NE.'C'.OR.FCHAR.NE.'c') GO TO 443
      WRITE (6,385)
 385  FORMAT (/2X,'GIVE THE POSITION AND THE RELATIVE MASS FLOW RATE TO'
     1/2X,'BE CHANGED IN THE FORM I,J,M    '/2X)
      READ(5,*,ERR=445) I,J,UBDY(I,J)
      GO TO 381
C
 391  IYPLUS = IY + 1
      WRITE(6,392) (J, J=1,IYPLUS)
 392  FORMAT(2X,'THE CURRENT VALUES OF Y VELOCITIES AT THE ZONE BOUNDARI
     1ES ARE'/2X,'I',4X,10(2X,'J =',I2,:,4X))
      DO 394 I = 1,IX
      WRITE(6,383) I,(VBDY(I,J),J=1,IYPLUS)
 394  CONTINUE
      WRITE(6,428)
      READ(5,402,ERR=443) FCHAR
      IF (FCHAR.EQ.'R'.OR.FCHAR.EQ.'r') GO TO 375
      IF (FCHAR.NE.'C'.OR.FCHAR.NE.'c') GO TO 443
      WRITE (6,385)
      READ(5,*,ERR=445) I,J,VBDY(I,J)
      GO TO 391
 398  GO TO 166
C
 402  FORMAT(A2)
 403  WRITE(6,405) FCO2,FH2O,FN2, FO2
 405  FORMAT(/2X,'THE CURRENT MASS FRACTIONS OF CO2,H2O,N2 AND O2 ARE',
     1/2X,F7.4/2X,F7.4/2X,F7.4/2X,F7.4/2X,'ENTER THE NEW MASS ',
     2'FRACTIONS IN THE SAME ORDER.   '/)
      READ(5,*,ERR=437) FCO2,FH2O,FN2,FO2
      GO TO 166
C
 410  WRITE(6,415)
 415  FORMAT(/2X,'THE CURRENT GAS TEMPERATURES ARE GIVEN BELOW IN',
     1' DEGREES K')
      WRITE(6,419) (J,J=1,IY)
 419  FORMAT (11X,10('J =',I2,:,5X) )
```

```
      DO 420 I=1,IX
      WRITE(6,425) I,(TEMP(I,J),J=1,IY)
 425  FORMAT (3X,'I=',I2,10(2X,F8.2))
 420  CONTINUE
      WRITE (6,428)
 428  FORMAT (/2X,'TYPE  C  TO CHANGE OR  R  TO RETURN TO PREVIOUS',
     1' SCREEN.  ')
      READ (5,402,ERR=443) FCHAR
      IF (FCHAR.EQ.'R'.OR.FCHAR.EQ.'r') GO TO 166
      IF (FCHAR.NE.'C'.OR.FCHAR.NE.'c') GO TO 443
      WRITE(6,430)
 430  FORMAT(/2X,'GIVE THE POSITION AND THE TEMPERATURE TO BE CHANGED IN
     1 THE FORM I,J,T     '/2X)
      READ (5,*,ERR=445) I,J,TEMP(I,J)
      GO TO 410
C
C      ERROR MESSAGES TO AVOID PROGRAM ABORTION
C
435   WRITE(6,436)
436   FORMAT(2X,'PLEASE ENTER INTEGER VALUE')
      GO TO (315,325,335,345,355,365,375,403,410,600), CHANGE1
C
437   WRITE(6,438)
438   FORMAT(2X,'ILLEGAL ENTRY - ENTER REAL NUMBER')
      GO TO (315,325,335,345,355,365,375,403,410,600), CHANGE1
C
441   WRITE(6,442)
442   FORMAT(2X,'ILLEGAL ENTRY - ENTER Y OR N')
      GO TO (315,325,335,345,355,365,375,403,410,600), CHANGE1
C
443   WRITE(6,444)
444   FORMAT(2X,'ILLEGAL ENTRY - ENTER C OR R')
      GO TO (315,325,335,345,355,365,375,403,410,600), CHANGE1
C
445   WRITE(6,446)
448   FORMAT(2X,'ILLEGAL ENTRY')
      GO TO (315,325,335,345,355,365,375,403,410,600), CHANGE1
C
C
C      EDIT FILE SECOND PART OF FILE
C
 600  WRITE(6,610)
 610  FORMAT(///,2X,'THE SECOND PART OF THE DATA FILE CONTAINS '
     1,/2X,'THE PROPERTIES OF A GIVEN DROPLET SPECIES, AS WELL'/2X,'AS S
     2OME FLAGS FOR OUTPUT CONTROL')
C
       ID = 2
       READ (ID,612) TBOIL,TLIQ
       READ (ID,612) CPLIQ, LHELIQ
       READ (ID,612) HCOMLQ
       READ (ID,612) RHOLIQ
       READ (ID,612) XNOZ, YNOZ
       READ (ID,614) NOZDIA, AFMRAT
       READ (ID,612) NSTEP, DSAFE
       READ (ID,612) TSAFE, ESAFE
      READ (ID,616) TOL1, NRAMP
      READ (ID,618) MAXSTP, NDROP
      READ (ID,618) NPRT1, NPRT2
      READ (ID,618) IOUT1, IOUT2
      READ (ID,618) IOUT3, IOUT4
      READ (ID,618) IOUT5, IOUT6
      READ (ID,618) INPTYP(1), INPTYP(2)
      READ (ID,618) INPTYP(3), INPTYP(4)
      READ (ID,618) INPTYP(5), INPTYP(6)
      READ (ID,617) TWDUM, TGDUM
      READ (ID,617) UDUM, VDUM
      READ (ID,618) TIMAX
 612  FORMAT(8X,F10.4,9X,F10.4)
 613  FORMAT(8X,F10.4,9X,E10.3)
 614  FORMAT(8X,E10.3,9X,F10.4)
 616  FORMAT(8X,F10.4,9X,I10)
 617  FORMAT(8X,F10.4,9X,F10.4)
 618  FORMAT(8X,I10,9X,I10)
C
C     WRITE CURRENT DATA TO SCREEN
C
 615  WRITE(6,620)  INCASE,TBOIL,TLIQ,CPLIQ,LHELIQ,HCOMLQ,RHOLIQ,
     1              XNOZ, YNOZ
 620  FORMAT(/2X,'THE FOLLOWING VALUES ARE CURRENTLY IN THIS FILE:'/
     12X,'1  NAME OF SPECIES',T30,40A1/
     12X,'2  BOILING TEMPERATURE  (K)',T45,F9.4/
     22X,'3  INITIAL DROPLET TEMPERATURE  (K)',T45,F9.4/
     32X,'4  LIQUID HEAT CAPACITY  (M**2/S**2/K)',T45,F9.4/
     42X,'5  LATENT HEAT OF EVAP.  (M**2/S**2)',T45, E10.3/
     42X,'6  HEAT OF COMBUSTION    (          )',T45, E10.3/
     52X,'7  LIQUID DENSITY  (KG/M**3)',T45,F9.4/
     52X,'8  INITIAL X POSITION  (M)',T45,F9.4/
     52X,'9  INITIAL Y POSITION  (M)',T45,F9.4)
C
      WRITE(6,630) NOZDIA,AFMRAT,NSTEP,DSAFE,TSAFE,ESAFE,TOL1
 630  FORMAT(1X,'10  NOZZLE DIAMETER (M)',T45,E10.3/
     11X,'11 AIR/FUEL MASS RATIO',T45,F9.4/
     11X,'12 APPROX. MINIMUM NO. OF STEPS IN ZONE',T45,F9.2/
     21X,'13  SAFETY FACTOR FOR DRAG TIMESTEP',T45,F9.4/
     31X,'14  SAFETY FACTOR FOR TEMP. TIMESTEP',T45,F9.4/
     41X,'15  SAFETY FACTOR FOR EVAP. TIMESTEP',T45,F9.4/
     51X,'16  TOLERANCE FOR APPROACHING FINAL VELOCITY',T45,F9.4/)
C
      WRITE(6,635)
 635  FORMAT(2X,'TYPE THE ITEM NUMBER (1-16) TO BE CHANGED.'/2X,'TYPE '
     1,'17 IF NO CHANGES ARE TO BE MADE.  ')
      READ (5,*) CHANGE3
      GO TO (701,702,703,704,705,740,706,741,742,707,708,709,710,711,
     1       712,713,638), CHANGE3
C
 638  WRITE(6,640) NRAMP,MAXSTP,NDROP,NPRT1,NPRT2,IOUT1,IOUT2
 640  FORMAT(1X,'1  TIMESTEP SIZE INCREASED OVER',T45,I3,' STEPS'/1X,
     1'2  MAXIMUM NO. OF STEPS IN LOOP',T45,I5/1X,'3  NUMBER OF ',
     2'DROPLETS INJECTED',T45,I4/1X,'4  TIMESTEP AT WHICH PRINTOUT ',
     3'BEGINS',T45,I4/1X,'5  MULTIPLES OF TIMESTEP FOR PRINTING',
     4T45,I5/1X,'6  GAS PROPERTIES PRINTED IF = 1',T45,I3/
     51X,'7  INCIN. PROP. PRINTED IF = 1',T45,I3)
C
      WRITE(6,650) IOUT3,IOUT4,IOUT5,IOUT6,INPTYP(1),INPTYP(2),INPTYP(3)
 650  FORMAT(1X,'8  DROP OUTPUT PRINTED IF = 1',T45,I3/
     11X,'9  FINAL SUMMARY PRINTED IF = 1',T45,I3/
     21X,'10  TURNS ON GRAVITY IF = 1',T45,I3/
     31X,'11  ADJUST RE FOR DRAG IN DROPLET TRAIN IF = 1',T45,I3/
     41X,'12  DUMMY TWALL IS READ IF = 1',T45,I3/
     51X,'13  DUMMY GAS TEMP. USED IF = 1',T45,I3/
     61X,'14  DUMMY X VELOCITY USED IF = 1',T45,I3)
C
      WRITE (6,660) INPTYP(4),TWDUM,TGDUM,UDUM,VDUM,TIMAX
 660  FORMAT(1X,'15  DUMMY Y VELOCITY USED IF = 1',T45,I3/
     11X,'16  DUMMY WALL TEMPERATURE',T45,F9.4/
     21X,'17  DUMMY GAS TEMPERATURE',T45,F9.4/
     31X,'18  DUMMY X VELOCITY',T45,F9.4/
     41X,'19  DUMMY Y VELOCITY',T45,F9.4/
     51X,'20  NO. OF TURBULENT RUNS',T45,I9)
C
      WRITE (6,670)
 670  FORMAT(/2X,'TYPE THE ITEM NUMBER (1-19) TO BE CHANGED.'/2X,
     1'TYPE  20  IF NO CHANGES ARE TO BE MADE.  ')
      READ (5,*) CHANGE3
      GO TO (714,715,716,717,718,719,720,721,722,723,724,725,726,
     1727,728,729,730,731,732,743,460), CHANGE3
C
C     CHANGE THE DATA
C
 701  WRITE (6,801)
 801  FORMAT (2X,'TYPE THE NEW NAME OF THE SPECIES  ')
      READ (5,611,ERR=435)  INCASE
      GO TO 615
C
 702  WRITE (6,802)
 802  FORMAT (2X,'TYPE THE NEW LIQUID BOILING TEMPERATURE (K)  ')
      READ (5,*,ERR=437) TBOIL
      GO TO 615
C
 703  WRITE( 6,803)
 803  FORMAT(2X,'TYPE THE NEW INITITAL DROPLET TEMPERATURE (K)  ')
      READ (5,*,ERR=437) TLIQ
      GO TO 615
C
 704  WRITE (6,804)
 804  FORMAT (2X,'TYPE THE NEW LIQUID HEAT CAPACITY (M*M/S/S/K)  ')
      READ (5,*,ERR=437) CPLIQ
      GO TO 615
C
 705  WRITE(6,805)
 805  FORMAT(2X,'TYPE THE NEW LATENT HEAT OF EVAPORATION (M**2/S**2)  ')
      READ (5,*,ERR=437) LHELIQ
      GO TO 615
C
 740  WRITE(6,840)
 840  FORMAT(2X,'TYPE THE NEW HEAT OF COMBUSTION  (     )  ')
      READ (5,*,ERR=437) HCOMLQ
      GO TO 615
C
 706  WRITE (6,806)
 806  FORMAT(2X,'TYPE THE NEW LIQUID DENSITY (KG/M**3)    ')
      READ (5,*,ERR=437) RHOLIQ
      GO TO 615
C
 741  WRITE (6,841)
 841  FORMAT(2X,'TYPE THE NEW INITIAL X POSITION (M)    ')
      READ (5,*,ERR=437) XNOZ
      GO TO 615
C
 742  WRITE (6,842)
 842  FORMAT(2X,'TYPE THE NEW INITIAL Y POSITION (M)    ')
      READ (5,*,ERR=437) YNOZ
      GO TO 615
C
 707  WRITE(6,807)
 807  FORMAT (2X,'TYPE THE NEW NOZZLE DIAMETER (M)  '/2X,
     1'IF THE NOZZLE DIAMETER WILL NOT AFFECT TROPLET VELOCITY, '/
     22X,'USE A NEGATIVE NUMBER    ')
      READ (5,*,ERR=437) NOZDIA
      GO TO 615
C
 708  WRITE (6,808)
 808  FORMAT (2X,'TYPE THE NEW AIR/FUEL MASS RATIO  ')
      READ (5,*,ERR=437) AFMRAT
      GO TO 615
C
 709  WRITE (6,809)
 809  FORMAT (2X,'TYPE THE NEW MINIMUM ZONE STEPS    ')
      READ (5,*,ERR=435) NSTEP
      GO TO 615
C
 710  WRITE (6,810)
 810  FORMAT(2X,'TYPE THE NEW DRAG TIMESTEP SAFETY FACTOR    ')
      READ (5,*,ERR=437)  DSAFE
      GO TO 615
C
 711  WRITE (6,811)
 811  FORMAT(2X,'TYPE THE NEW TEMP. TIMESTEP SAFETY FACTOR    ')
      READ (5,*,ERR=437)  TSAFE
      GO TO 615
C
 712  WRITE (6,812)
 812  FORMAT(2X,'TYPE THE NEW EVAP. TIMESTEP SAFETY FACTOR    ')
      READ (5,*,ERR=437)  ESAFE
      GO TO 615
C
 713  WRITE (6,813)
 813  FORMAT(2X,'TYPE NEW TOLERANCE FOR EVAP. DIAMETER     ')
      READ (5,*,ERR=437) TOL1
      GO TO 615
```

```
C
 714  WRITE (6,814)
 814  FORMAT (2X,'TYPE THE NEW RAMP FOR TIMESTEP   ')
      READ (5,*,ERR=435) NRAMP
      GO TO 638
C
 715  WRITE (6,815)
 815  FORMAT(2X,'TYPE THE NEW MAX. NO. OF STEPS  ')
      READ (5,*,ERR=435) MAXSTP
      GO TO 638
C
 716  WRITE (6,816)
 816  FORMAT (2X,'TYPE THE NEW NUMBER OF DROPLETS   ')
      READ (5,*,ERR=435) NDROP
      GO TO 638
C
 717  WRITE   (6,817)
 817  FORMAT(2X,'TYPE THE NEW TIMESTEP FOR PRINTOUT TO BEGIN   ')
      READ (5,*,ERR=435) NPRT1
      GO TO 638
C
 718  WRITE (6,818)
 818  FORMAT (2X,'TYPE THE NEW TIMESTEP INCREMENT FOR PRINTOUT   ')
      READ (5,*,ERR=435) NPRT2
      GO TO 638
C
 719  WRITE (6,819)
 819  FORMAT(2X,'TYPE THE NEW FLAG FOR GAS PROPERTIES   ')
      READ (5,*,ERR=435) IOUT1
      GO TO 638
C
 720  WRITE (6,820)
 820  FORMAT(2X,'TYPE THE NEW FLAG FOR INCIN. PROPERTIES   ')
      READ (5,*,ERR=435) IOUT2
      GO TO 638
C
 721  WRITE (6,821)
 821  FORMAT(2X,'TYPE THE NEW FLAG FOR PRINTING OUTPUT   ')
      READ (5,*,ERR=435) IOUT3
      GO TO 638
C
 722  WRITE (6,822)
 822  FORMAT(2X,'TYPE THE NEW FLAG FOR PRINTING RESULTS  ')
      READ (5,*,ERR=435) IOUT4
      GO TO 638
C
 723  WRITE (6,823)
 823  FORMAT(2X,'TYPE THE NEW FLAG FOR USING GRAVITY  ')
      READ (5,*,ERR=435) IOUT5
      GO TO 638
C
 724  WRITE (6,824)
 824  FORMAT(2X,'TYPE THE NEW FLAG FOR DROPLET TRAIN  ')
      READ (5,*,ERR=435) IOUT6
      GO TO 638
```

```
C
 725  WRITE (6,825)
 825  FORMAT(2X,'TYPE THE NEW DUMMY TWALL FLAG   ')
      READ (5,*,ERR=435) INPTYP(1)
      GO TO 638
C
 726  WRITE (6,826)
 826  FORMAT(2X,'TYPE THE NEW DUMMY GAS TEMPERATURE FLAG   ')
      READ (5,*,ERR=435) INPTYP(2)
      GO TO 638
C
 727  WRITE (6,827)
 827  FORMAT(2X,'TYPE THE NEW DUMMY X VELOCITY FLAG   ')
      READ (5,*,ERR=435) INPTYP(3)
      GO TO 638
C
 728  WRITE (6,828)
 828  FORMAT(2X,'TYPE THE NEW DUMMY Y VELOCITY FLAG   ')
      READ (5,*,ERR=435) INPTYP(4)
      GO TO 638
C
 729  WRITE (6,829)
 829  FORMAT(2X,'TYPE THE NEW DUMMY WALL TEMPERATURE   ')
      READ (5,*,ERR=437) TWDUM
      GO TO 638
C
 730  WRITE (6,830)
 830  FORMAT(2X,'TYPE THE NEW DUMMY GAS TEMPERATURE   ')
      READ (5,*,ERR=437) TGDUM
      GO TO 638
C
 731  WRITE (6,831)
 831  FORMAT(2X,'TYPE THE NEW DUMMY X VELOCITY    ')
      READ (5,*,ERR=437) UDUM
      GO TO 638
C
 732  WRITE (6,832)
 832  FORMAT(2X,'TYPE THE NEW DUMMY Y VELOCITY   ')
      READ (5,*,ERR=437) VDUM
      GO TO 638
C
 743  WRITE (6,843)
 843  FORMAT(2X,'TYPE THE NEW NO. OF TURBULENT RUNS   ')
      READ (5,*,ERR=437) TIMAX
      GO TO 638
C
C     EDIT INITITAL DROPLET PROPERTIES
C
460   DO 462 I = 1,NDROP
      READ(4,461) XPOLD(1),YPOLD(I),UPOLD(I),VPOLD(I),DINIT(I),LOD(I)
 461  FORMAT(8X,F10.4,9X,F10.4/8X,F10.4,9X,F10.4/8X,E10.3,9X,F10.4)
 462  CONTINUE
      REWIND 4
 463  WRITE(6,464)
 464  FORMAT(/'Q THE THIRD PART OF THE DATA FILE CONTAINS THE',
     1' CHARACTERISTICS OF EACH'/2X,' INJECTED DROP.  THE CURRENT FILE',
     2'CONTAINS THE FOLLOWING VALUES'//1X,'NUMBER',3X,'INITIAL DIA',
     3'   INITIAL X   INITIAL Y   INITIAL U   INITIAL V    L/D    ',/14X,
     4'(M)',10X,'(M)',9X,'(M)',8X,'(M/S)',7X,'(M/S)')
      DO 470 I = 1,NDROP
      WRITE (6,465) I,DINIT(I),XPOLD(I),YPOLD(I),UPOLD(I),VPOLD(I)
     1,LOD(I)
 465  FORMAT (3X,I2,3X,F8.5,4(3X,F10.3),3X,F7.4)
 470  CONTINUE
C
C     CHANGE THE DATA
C
 480  WRITE (6,485)
 485  FORMAT(/2X,'DO YOU DESIRE TO CHANGE DROPLET DATA, CHANGE THE ',
     1'NUMBER OF DROPLETS, OR QUIT?'/2X,'TYPE  C  OR  N  OR  Q .   ')
      READ (5,402) ECHAR
      IF (ECHAR.EQ.'C'.OR.ECHAR.EQ.'c') GO TO 500
      IF (ECHAR.EQ.'Q'.OR.ECHAR.EQ.'q') GO TO 565
      IF (ECHAR.NE.'N'.OR.ECHAR.NE.'n') GO TO 480

C
      WRITE (6,481) NDROP
 481  FORMAT (/2X,'CURRENT NUMBER OF DROPLETS IS ',I2,/2X,
     1'TYPE THE NEW NUMBER OF DROPLETS TO BE TESTED.  ')

      READ (5,*,ERR=435) NDROP
      GO TO 500
C
 500  WRITE(6,510)
 510  FORMAT(2X,'LIST THE DATA TO BE CHANGED OR ADDED.'/5X,'NUMBER  ')
      READ (5,*,ERR=435) I
      WRITE(6,520)
 520  FORMAT(5X,'DIAMETER  ')
      READ (5,*,ERR=437) DINIT(I)
      WRITE (6,530)
 530  FORMAT (5X,'INITIAL X POSITION OF DROPLET   ')
      READ (5,*,ERR=437) XPOLD(I)
      WRITE (6,540)
 540  FORMAT (5X,'INITIAL Y POSITION OF DROPLET   ')
      READ (5,*,ERR=437) YPOLD(I)
      WRITE (6,550)
 550  FORMAT (5X,'INITIAL X VELOCITY OF DROPLET   ')
      READ (5,*,ERR=437) UPOLD(I)
      WRITE (6,560)
 560  FORMAT (5X,'INITIAL Y VELOCITY OF DROPLET   ')
      READ (5,*,ERR=437) VPOLD(I)
      WRITE (6,562)
 562  FORMAT (5X,'INITIAL DROPLET SPACING  (L/D)   ')
      READ (5,*,ERR=437) LOD(I)
      GO TO 463
C
C     SAVE THE NEW DATA - PART 1
C
 565  REWIND 2
      IXPLUS = IX + 1
      IYPLUS = IY + 1
```

```
  570  WRITE (ID,575) CASE1
  575  FORMAT (80A1)
       WRITE (ID,580) IX,IY
  580  FORMAT (2I4)
       WRITE (ID,590) (XL(J),J=1,IX)
  590  FORMAT (10F8.5)
       WRITE (ID,585) (R(J),J=1,IY)
  585  FORMAT (5F8.5)
       WRITE (ID,591) MDOTIN
       WRITE (ID,591) FCO2,FH2O,FN2,FO2
  591  FORMAT (4F8.5)
C
       DO 593 I = 1,IXPLUS
       WRITE (ID,592) (UBDY(I,J), J=1,IY)
  592  FORMAT (5F8.4)
  593  CONTINUE
C
       DO 595 J=1,IYPLUS
       WRITE (ID,594) (VBDY(I,J) ,I=1,IX)
  594  FORMAT (10F8.4)
  595  CONTINUE
C
       DO 597 I = 1,IX
       WRITE (ID,596) (TEMP(I,J),J=1,IY)
  596  FORMAT (5F8.2)
  597  CONTINUE
C
C      SAVE THE NEW DATA - PART 2
C
  735  WRITE(ID,745) TBOIL,TLIQ
  745  FORMAT('TBOIL  :',F10.4,' TLIQ   :',F10.4)
       WRITE(ID,750) CPLIQ,LHELIQ
  750  FORMAT('CPLIQ  :',F10.4,' LHELIQ :',E10.4)
       WRITE(ID,752) RHOLIQ
  752  FORMAT('RHOLIQ :',F10.4)
       WRITE(ID,755) NOZDIA,AFMRAT
  755  FORMAT('NOZDIA :',E10.4,' AFMRAT :',F10.4)
       WRITE(ID,756) NSTEP,DSAFE
  756  FORMAT('NSTEP  :',F10.4,' DSAFE  :',F10.4)
       WRITE(ID,758) TSAFE,ESAFE
  758  FORMAT('TSAFE  :',F10.4,' ESAFE  :',F10.4)
       WRITE(ID,760) TOL1,NRAMP
  760  FORMAT('TOL1   :',F10.4,' NRAMP  :',I10)
       WRITE(ID,763) MAXSTP,NDROP
  763  FORMAT('MAXSTP :',I10/'NDROP  :',I10)
       WRITE(ID,765) NPRT1,NPRT2
  765  FORMAT('NPRT1  :',I10/'NPRT2  :',I10)
       WRITE(ID,766) IOUT1,IOUT2
  766  FORMAT('IOUT1  :',I10/'IOUT2  :',I10)
       WRITE(ID,768) IOUT3,IOUT4
  768  FORMAT('IOUT3  :',I10/'IOUT4  :',I10)
       WRITE(ID,770) IOUT5,IOUT6
  770  FORMAT('IOUT5  :',I10/'IOUT6  :',I10)
       WRITE(ID,772) INPTYP(1),INPTYP(2)
  772  FORMAT('INPTYP1:',I10/'INPTYP2:',I10)
```

```
      WRITE(ID,774) INPTYP(3),INPTYP(4)
  774 FORMAT('INPTYP3:',I10/'INPTYP4:',I10)
      WRITE(ID,776) INPTYP(5),INPTYP(6)
  776 FORMAT('INPTYP5:',I10/'INPTYP6:',I10)
      WRITE(ID,778) TWDUM,TGDUM
  778 FORMAT ('TWDUM  :',F10.4,' TGDUM  :',F10.4)
      WRITE(ID,779) UDUM,VDUM
  779 FORMAT('UDUM   :',F10.4,' VDUM   :',F10.4)
      WRITE(ID,781) TIMAX
  781 FORMAT ('L/D    :',I10)
      CLOSE (UNIT=3)
C
C     SAVE NEW DATA - PART 3
C
  850 DO 890 I = 1,NDROP
      IF (XPOLD(I).EQ.999) GO TO 890
      WRITE(ID,860) XPOLD(I), YPOLD(I)
  860 FORMAT ('XPOLD  :',F10.4,' YPOLD  :',F10.4)
      WRITE(ID,870) UPOLD(I), VPOLD(I)
  870 FORMAT ('UPOLD  :',F10.4,' VPOLD  :',F10.4)
      WRITE(ID,880) DINIT(I), LOD(I)
  880 FORMAT ('DINIT  :',E10.3,' L/D    :',F10.4)
  890 CONTINUE
      CLOSE (UNIT=2)
  900 STOP
      END
C     -----------------------------------------------------------------
      SUBROUTINE THREED
C
C     THIS IS A PROGRAM TO EDIT THE FILE NAMED ICDINC.INP
C     DATA FOR THE 3-DIMENSIONAL DROPLET INJECTION MODEL
C
      LOGICAL*1 LABEL(70,5),INCASE(40), CASE(45)
      REAL MDOTIN, LOD
      REAL LHELIQ, NOZDIA, TBOIL, UBDY(26,15,5), VBDY(25,16,5)
      REAL WBDY(25,15,2),LOD
      INTEGER CHANGE2, CHANGE3, CHANGE4
      CHARACTER ACHAR, FCHAR
      DIMENSION XL(25),R(15),DTHETA(5),TEMP(25,15,5),INJOUT(6),INPTYP(6)
      OPEN (7,STATUS='UNKNOWN',FILE='DROP3D.DAT')
      READ (7,1001)  (CASE(I), I=1,45)
 1000 FORMAT (80A1)
 1001 FORMAT (2X,45A1)
      READ (7,1010) IX, IY, IZ
 1010 FORMAT(3X,3(I4,5X))
C
      I1=1
      I2=5
      DO 1020 L=1,IX
      IF (IX.LT.I2) I2=IX
      READ (7,1030) (XL(I),I=I1,I2)
 1030 FORMAT(15X,5(1X,F8.4))
      I1 = I2 + 1
      I2 = I1 + 4
      IF (I1.GT.IX) GO TO 1040
 1020 CONTINUE
 1040 CONTINUE
C
      I1 = 1
      I2 = 5
      DO 1050 L = 1,IY
      IF (IY.LT.I2) I2 = IY
      READ(7,1030) (R(J), J=I1,I2)
      I1 = I2 + 1
      I2 = I1 + 4
      IF (I1.GT.IY) GO TO 1060
 1050 CONTINUE
 1060 CONTINUE
C
      I1 = 1
      I2 = 5
      DO 1070 L = 1,IZ
      IF (IZ.LT.I2) I2 = IZ
      READ(7,1030) (DTHETA(K), K=I1,I2)
      I1 = I2 + 1
      I2 = I1 + 4
      IF (I1.GT.IZ) GO TO 1080
 1070 CONTINUE
 1080 CONTINUE
C
      READ (7,1090) MDOTIN
 1090 FORMAT(8X,F8.5)
      READ (7,1100) FCO2O2, FH2O, FN2, FO2
 1100 FORMAT(4(6X,F8.5))
C
      IYPLUS = IY + 1
      READ (7,1000) (LABEL(I,2), I=1,70)
      DO 1145 I=1,IX
      I1=1
      I2=8
      DO 1130 L=1,IX
      IF (IYPLUS.LT.I2) I2=IYPLUS
      READ (7,1120) (VBDY(I,J,1),J=I1,I2)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IYPLUS) GO TO 1140
 1130 CONTINUE
 1140 CONTINUE
 1145 CONTINUE
C
      IZPLUS = IZ + 1
      READ (7,1000) (LABEL(I,3), I=1,70)
      DO 1150 K=1,IZPLUS
      DO 1150 I=1,IX
      I1=1
      I2=8
      DO 1160 L=1,IX
      IF (IY.LT.I2) I2=IY
      READ (7,1120) (WBDY(I,J,K),J=I1,I2)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IY) GO TO 1155
 1160 CONTINUE
 1155 CONTINUE
 1150 CONTINUE
C
C     GAS TEMPERATURES
C
      READ (7,1000) (LABEL(I,4), I=1,70)
      DO 1185 I=1,IX
      I1=1
      I2=8
      DO 1175 L=1,IX
      IF (IX.LT.I2) I2=IY
      READ (7,1165) (TEMP(I,J,1),J=I1,I2)
 1165 FORMAT (8F8.2)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IY) GO TO 1180
 1175 CONTINUE
 1180 CONTINUE
 1185 CONTINUE
C
C      VELOCITIES IN THE POSITIVE I DIRECTION
C
      IXPLUS = IX + 1
      READ (7,1000) (LABEL(I,1), I=1,70)
      DO 1195 I=1,IXPLUS
      I1=1
      I2=8
      DO 1190 L=1,IX
      IF (IX.LT.I2) I2=IY
      READ (7,1120) (UBDY(I,J,1),J=I1,I2)
 1120 FORMAT(8F8.4)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IY) GO TO 1195
 1190 CONTINUE
 1195 CONTINUE
C
      READ (7,1205) (INCASE (I), I=1,40)
 1205 FORMAT(40A1)
      READ (7,1220) TBOIL,TLIQ
 1220 FORMAT(8X,F10.4,9X,F10.4)
C
      READ (7,1230) CPLIQ, LHELIQ
 1230 FORMAT (8X,F10.4,9X,E10.3)
C
      READ (7,1240) HCOMLQ
 1240 FORMAT (8X,E10.3,9X,F10.4)
C
      READ (7,1220) RHOLIQ, XNOZ
      READ (7,1220) YNOZ, ZNOZ
      READ (7,1240) NOZDIA, AFMRAT
C
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```
      READ (7,1220) ZSAFE, DSAFE
      READ (7,1220) TSAFE, ESAFE
C
      READ(7,1250) TOL1, NRAMP
 1250 FORMAT (8X,F10.4,9X,I10)
C
      READ(7,1260) MAXSTP,NDROP
 1260 FORMAT(8X,I10/8X,I10)
C
      READ(7,1260) NPRT1, NPRT2
      READ (7,1265) NPRT3
 1265 FORMAT (8X,I10)
C
      READ (7,1270) INJOUT(1), INJOUT(2)
      READ (7,1270) INJOUT(3), INJOUT(4)
      READ (7,1270) INJOUT(5), INJOUT(6)
      READ (7,1270) INPTYP(1), INPTYP(2)
      READ (7,1270) INPTYP(3), INPTYP(4)
      READ (7,1270) INPTYP(5), INPTYP(6)

 1270 FORMAT(8X,I10/8X,I10)
C
      READ (7,1280) TWDUM, TGDUM
      READ (7,1280) UDUM, VDUM
      READ (7,1280) SWIRL, TOTLEN
 1280 FORMAT (8X,F10.4,9X,F10.4)
      READ (7,1260) JLAYER, JFORCE
      READ (7,1285) TIMAX
 1285 FORMAT (8X,E10.3)
C
      READ (7,1290) DINIT
 1290 FORMAT (8X,E10.3)
C
      READ (7,1295) DRPVEL
      READ (7,1295) XPCOMP
      READ (7,1295) YPCOMP
      READ (7,1295) ZPCOMP
      READ (7,1295) LOD
 1295 FORMAT (8X,F10.4)
      REWIND 7
C
C
C
 1300 WRITE(6,1310) (CASE(I), I=1,45)
 1310 FORMAT (2X,'THE INFORMATION FOR THE CASE TO BE ANALYZED IS'/2X,
     1'GIVEN BELOW. CASE TITLE: ',45A1)
      WRITE (6,1320)
 1320 FORMAT (/6X,'1  CASE NAME')
      WRITE (6,1330)
 1330 FORMAT(6X,'2  NUMBER OF AXIAL ZONES'/6X,'3  NUMBER OF RADIAL',
     1' ZONES'/6X,'4  NUMBER OF TANGENTIAL DIVISIONS')
      WRITE(6,1340)
 1340 FORMAT(6X,'5  AXIAL LENGTHS OF ZONE BOUNDARIES'/6X,'6  RADIAL',
     1' LOCATIONS OF ZONE BOUNDARIES'/6X,'7  ANGULAR MEASUREMENTS OF',
     2' EACH ZONE')
```

```
      WRITE(6,1350)
 1350 FORMAT(6X,'8  TOTAL MASS FLOW RATE'/6X,'9  MASS FRACTIONS OF ',
     1'CO2,H2O,N2,O2'/5X,'10  RELATIVE INPUT VELOCITIES')
      WRITE (6,1360)
 1360 FORMAT(5X,'11  GAS TEMPERATURES'//2X,'TYPE THE NUMBER OF THE ',
     1'VALUE TO BE CHANGED.'/2X,'IF NO CHANGES ARE TO BE MADE ',
     2'TYPE 12.      ')
C
      READ (5,*) CHANGE4
      GO TO (1400,1450,1480,1510,1540,1580,1600,1620,1650,1680,1710,
     11810), CHANGE4
C
 1400 WRITE (6,1410) (CASE(I), I=1,45)
 1410 FORMAT (/2X,'CURRENT CASE TITLE IS  ',45A1/2X,'TYPE  C  TO ',
     1'CHANGE IT OR  R  TO RETURN TO PREVIOUS SCREEN  ')
      READ (5,1420) ACHAR
 1420 FORMAT (A1)
      IF (ACHAR.EQ.'R') GO TO 1300
      WRITE (6,1430)
 1430 FORMAT (/2X,' ENTER NEW CASE TITLE:  ')
      READ (5,1440) (CASE(I), I=1,45)
 1440 FORMAT (45A1)
      GO TO 1300
C
 1450 WRITE(6,1460) IX
 1460 FORMAT(/2X,'CURRENT NUMBER OF AXIAL ZONES IS ',I2,
     1',  ENTER NEW VALUE:  ')
      READ(5,*) IX
      GO TO 1300
C
 1480 WRITE(6,1490) IY
 1490 FORMAT(/2X,'CURRENT NUMBER OF RADIAL ZONES IS ',I2,
     1'.  ENTER NEW VALUE:  ')
      READ (5,*) IY
      GO TO 1300
C
 1510 WRITE(6,1520) IZ
 1520 FORMAT(/2X,'CURRENT NUMBER OF CIRCUMFERENTIAL ZONES IS ',I2,
     1'.  ENTER NEW VALUE:  ')
      READ (5,*) IZ
      GO TO 1300
C
 1540 WRITE(6,1550) (J,XL(J),J=1,IX)
 1550 FORMAT(/2X,'THE CURRENT VALUES OF AXIAL ZONE LENGTH ARE'/
     1(6X,I2,4X,F6.3))
      WRITE (6,1560)
 1560 FORMAT(2X,'ARE ANY OF THESE VALUES TO BE CHANGED?  Y OR N  ')
      READ(5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1300
      WRITE(6,1570)
 1570 FORMAT(2X,'ENTER NEW ZONE NUMBER AND CORRESPONDING POSITION   ')
      READ(5,*) I,XL(I)
      GO TO 1540
C
 1580 WRITE(6,1590) (I,R(I), I = 1,IY)
 1590 FORMAT(/2X,'THE CURRENT RADIAL ZONE POSITIONS:'/(6X,I2,4X,F6.3))
      WRITE (6,1560)
      READ (5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1300
      WRITE (6,1570)
      READ(5,*) I,R(I)
      GO TO 1580
C
 1600 WRITE(6,1610) (I,DTHETA(I),I = 1,IZ)
 1610 FORMAT(/2X,'THE ANGULAR DIVISIONS (IN DEGREES) ARE:'
     1/(6X,I2,4X,F6.1))
      WRITE(6,1560)
      READ (5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1300
      WRITE (6,1570)
      READ(5,*) I,DTHETA(I)
      GO TO 1600
C
 1620 WRITE(6,1630) MDOTIN
 1630 FORMAT(/2X,'THE CURRENT MASS FLOW RATE IS',F6.3,' KG/SEC.')
      WRITE(6,1635)
 1635 FORMAT(2X,'IS THIS VALUE TO BE CHANGED?  Y OR N  ')
      READ (5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1300
      WRITE (6,1640)
 1640   FORMAT(2X,'NEW MASS FLOW RATE:  ')
      READ(5,*) MDOTIN
      GO TO 1300
C
 1650 WRITE(6,1660) FCO2,FH2O,FN2, FO2
 1660 FORMAT(/2X,'THE CURRENT MASS FRACTIONS OF CO2,H2O,N2 AND O2 ARE',
     1/10X,'1. CO2 :  ',F5.3,6X,'3. N2  :  ',F5.3/10X,
     2'2. H2O :  ',F5.3,6X,'4. O2  :  ',F5.3)
      WRITE(6,1560)
      READ(5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1300
      WRITE(6,1670)
 1670 FORMAT(2X,'TYPE NEW MASS FRACTIONS IN THE ORDER LISTED ABOVE'/3X)
      READ(5,*) FCO2,FH2O,FN2,FO2
      GO TO 1300
C
 1680 WRITE(6,1690)
 1690 FORMAT(/2X,'WHICH OF THE FOLLOWING DO YOU WISH TO ',
     1'CHANGE?'//2X,'1 - X DIRECTION VELOCITIES',/2X,
     2'2 - Y DIRECTION VELOCITIES',/2X,'3 - Z DIRECTION VELOCITIES'
     3//2X, 'TYPE 4 IF NO CHANGES ARE TO BE MADE   ')
      READ(5,*)  CHANGE2
      GO TO (1691,1701,1706,1300), CHANGE2
C
 1691 IXPLUS = IX + 1
      WRITE(6,1692) (J, J=1,IY)
 1692 FORMAT (2X,'THE CURRENT VALUES OF X VELOCITIES AT THE ZONE',
     1' BOUNDARIES ARE'/3X,'I',2X,8(2X,'J =',I2,:,2X))
      DO 1694 I = 1,IXPLUS
      WRITE (6,1693) I,(UBDY(I,J,1), J=1,IY)
 1693 FORMAT(2X,I2,8(2X,F7.3))
 1694 CONTINUE
      WRITE (6,1560)
      READ (5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1680
      WRITE (6,1695)
 1695 FORMAT (/2X,'ENTER THE I AND J COORDINATES AND THE NEW VALUE'
     1/2X,'FOR X VELOCITY IN THE FORM I,J,U     '/2X)
      READ(5,*) I,J,UBDY(I,J,1)
      GO TO 1691
C
 1701 IYPLUS = IY + 1
      WRITE(6,1702) (J, J=1,IYPLUS)
 1702 FORMAT(2X,'THE CURRENT VALUES OF Y VELOCITIES AT THE ZONE BOUNDARI
     1ES ARE'/3X,'I',2X,8(2X,'J =',I2,:,2X))
      DO 1704 I = 1,IX
      WRITE(6,1693) I,(VBDY(I,J,1),J=1,IYPLUS)
 1704 CONTINUE
      WRITE(6,1560)
      READ(5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1680
      WRITE (6,1695)
      READ(5,*) I,J,VBDY(I,J,1)
      GO TO 1701
C
 1706 IZPLUS = IZ + 1
      WRITE (6,1708) IZPLUS
 1708 FORMAT (2X,'WHICH RADIAL ZONE DO YOU WISH TO CHANGE? 1 - ',I2)
      READ (5,1709) K
 1709 FORMAT (I2)
      WRITE(6,1707) (J, J=1,IY)
 1707 FORMAT(2X,'THE CURRENT VALUES OF Z VELOCITIES AT THE ZONE BOUNDARI
     1ES ARE'/3X,'I',2X,8(2X,'J =',I2,:,2X))
      DO 1711 I = 1,IX
      WRITE(6,1693) I,(WBDY(I,J,K),J=1,IY)
 1711 CONTINUE
      WRITE(6,1560)
      READ(5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1680
      WRITE (6,1695)
      READ(5,*) I,J,WBDY(I,J,K)
      GO TO 1706
C
 1710 WRITE(6,1720)
 1720 FORMAT(/2X,'THE CURRENT GAS TEMPERATURES ARE GIVEN BELOW IN',
     1' DEGREES K')
      WRITE(6,1730) (J,J=1,IY)
 1730 FORMAT (11X,8('J =',I2,:,4X) )
      DO 1750 I=1,IX
      WRITE(6,1740) I,(TEMP(I,J,1),J=1,IY)
 1740 FORMAT (3X,'I=',I2,8(1X,F8.2))
 1750 CONTINUE
      WRITE (6,1560)
      READ (5,1420) FCHAR
      IF (FCHAR.EQ.'N') GO TO 1300
      WRITE(6,1760)
 1760 FORMAT(/2X,'GIVE THE POSITION AND THE TEMPERATURE TO BE CHANGED IN
     1 THE FORM I,J,T    '/2X)
      READ (5,*) I,J,TEMP(I,J,1)
      GO TO 1710
C
C     SAVE THE NEW DATA
C
 1810 WRITE (7,1820) (CASE(I), I=1,45)
 1820 FORMAT (2X,45A1)
      WRITE(7,1830) IX, IY, IZ
 1830 FORMAT ('IX:',I4,' IY:',I4,' IZ:',I4)
C
      I1 = 1
      I2 = 5
      DO 1850 L = 1,IX
      IF (IX.LT.I2) I2 = IX
      WRITE(7,1840) I1,I2,(XL(I),I=I1,I2)
 1840 FORMAT ('XL(',I2,'-',I2,')      :',5(1X,F8.4))
      I1 = I2 + 1
      I2 = I1 + 4
      IF (I1.GT.IX) GO TO 1860
 1850 CONTINUE
 1860 CONTINUE
C
      I1 = 1
      I2 = 5
      DO 1880 L = 1,IY
      IF (IY.LT.I2) I2 = IY
      WRITE(7,1870) I1,I2,(R(I),I=I1,I2)
 1870 FORMAT ('R(',I2,'-',I2,')        :',5(1X,F8.4))
      I1 = I2 + 1
      I2 = I1 + 4
      IF (I1.GT.IY) GO TO 1890
 1880 CONTINUE
 1890 CONTINUE
C
      I1 = 1
      I2 = 5
      DO 1910 L = 1,IZ
      IF (IZ.LT.I2) I2 = IZ
      WRITE(7,1900) I1,I2,(DTHETA(I),I=I1,I2)
 1900 FORMAT ('DTHETA(',I2,'-',I2,')  :',5(1X,F8.4))
      I1 = I2 + 1
      I2 = I1 + 4
      IF (I1.GT.IZ) GO TO 1920
 1910 CONTINUE
 1920 CONTINUE
C
      WRITE (7,1930) MDOTIN
 1930 FORMAT ('MDOTIN :',F8.5)
      WRITE (7,1940) FCO2,FH2O,FN2,FO2
 1940 FORMAT('FCO2 :',F7.4,' FH2O :',F7.4,' FN2  :',F7.4,' FO2  :',F7.4)
C
C     VELOCITIES IN THE AXIAL DIRECTION
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```
C
      IXPLUS = IX + 1
      WRITE (7,1000) (LABEL(I,1), I=1,70)
      DO 1995 I=1,IXPLUS
      I1=1
      I2=8
      DO 1993 L=1,IX
      IF (IY.LT.I2) I2=IY
      WRITE (7,1120) (UBDY(I,J,1),J=I1,I2)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IY) GO TO 1995
 1993 CONTINUE
 1995 CONTINUE
C
C        RADIAL VELOCITIES
C
      IYPLUS = IY + 1
      WRITE (7,1000) (LABEL(I,2), I=1,70)
      DO 1950 I=1,IX
      I1=1
      I2=8
      DO 1955 L=1,IX
      IF (IYPLUS.LT.I2) I2=IYPLUS
      WRITE (7,1120) (VBDY(I,J,1),J=I1,I2)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IYPLUS) GO TO 1960
 1955 CONTINUE
 1960 CONTINUE
 1950 CONTINUE
C
      IZPLUS = IZ + 1
      WRITE (7,1000) (LABEL(I,3), I=1,70)
      DO 1975 K=1,IZPLUS
      DO 1970 I=1,IX
      I1=1
      I2=8
      DO 1965 L=1,IX
      IF (IY.LT.I2) I2=IY
      WRITE (7,1120) (WBDY(I,J,K),J=I1,I2)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IY) GO TO 1970
 1965 CONTINUE
 1970 CONTINUE
 1975 CONTINUE
C
C       GAS TEMPERATURES
C
      WRITE (7,1000) (LABEL(I,4), I=1,70)
      DO 1990 I=1,IX
      I1=1
      I2=8
      DO 1980 L=1,IX
      IF (IY.LT.I2) I2=IY
      WRITE (7,1981) (TEMP(I,J,1),J=I1,I2)
 1981 FORMAT (8F8.2)
      I1 = I2 + 1
      I2 = I1 + 7
      IF (I1.GT.IY) GO TO 1985
 1980 CONTINUE
 1985 CONTINUE
 1990 CONTINUE
C
 2000 WRITE (6,2010) (INCASE(I), I=1,40)
 2010 FORMAT(/2X,'THE FOLLOWING VALUES ARE CURRENTLY IN THIS FILE:'/
     12X,'1  NAME OF DROPLET FUEL',T30,40A1)
      WRITE(6,2015) TBOIL,TLIQ,CPLIQ,LHELIQ,HCOMLQ,RHOLIQ,XNOZ,YNOZ,ZNOZ
 2015 FORMAT(2X,'2  BOILING TEMPERATURE  (K)',T45,F9.4/
     22X,'3  INITIAL DROPLET TEMPERATURE  (K)',T45,F9.4/
     32X,'4  LIQUID HEAT CAPACITY  (M**2/S**2/K)',T45,F9.4/
     42X,'5  LATENT HEAT OF EVAP.  (M**2/S**2)',T45, E10.3/
     52X,'6  LIQUID DENSITY  (KG/M**3)',T45,F9.4/
     52X,'7  HEAT OF COMBUSTION (      )',T45,E10.3/
     62X,'8  NOZZLE COORDINATES (M) X, Y, Z',T45,3(F9.4))
C
      WRITE(6,2020) NOZDIA,AFMRAT,ZSAFE,DSAFE,TSAFE,ESAFE,TOL1
 2020 FORMAT(2X,'9  NOZZLE DIAMETER (M)',T45,E10.3/
     11X,'10 AIR/FUEL MASS RATIO',T45,F9.4/
     11X,'11  SAFETY FACTOR FOR ZONE TIMESTEP',T45,F9.2/
     21X,'12  SAFETY FACTOR FOR DRAG TIMESTEP',T45,F9.2/
     31X,'13  SAFETY FACTOR FOR TEMP. TIMESTEP',T45,F9.2/
     41X,'14  SAFETY FACTOR FOR EVAP. TIMESTEP',T45,F9.2/
     51X,'15  TOLERANCE FOR APPROACHING FINAL VELOCITY',T46,F8.4)
C
      WRITE(6,2040) NRAMP,MAXSTP,NDROP,NPRT1,NPRT2,NPRT3
 2040 FORMAT(1X,'16  TIMESTEP SIZE INCREASED OVER',T45,I3,' STEPS'/
     11X,'17  MAXIMUM NO. OF STEPS IN LOOP',T45,I5/
     21X,'18  NUMBER OF DROPLETS INJECTED',T45,I4/
     31X,'19  TIMESTEP AT WHICH PRINTOUT BEGINS',T45,I4/
     41X,'20  MULTIPLES OF TIMESTEP FOR PRINTING',T45,I5/
     51X,'21  INCREMENT COUNTER FOR INJECTED DROPS',T45,I5)
C
      WRITE(6,2045)
 2045 FORMAT(/2X,'TYPE THE ITEM NUMBER (1-21) TO BE CHANGED.'/2X,'TYPE '
     1,'22 IF NO CHANGES ARE TO BE MADE.  ')
      READ (5,*) CHANGE3
      GO TO (2101,2102,2103,2104,2105,2106,2141,2107,2108,2109,2110,
     12111,2112,2113,2114,2115,2116,2117,2118,2119,2120,2049), CHANGE3
C
 2049 WRITE (6,2030) INJOUT(1)
 2030 FORMAT(/2X,'THE FOLLOWING VALUES ARE CURRENTLY IN THIS FILE:'//
     12X,'1  GAS PROPERTIES PRINTED IF = 1',T45,I3)
      WRITE(6,2050) INJOUT(2),INJOUT(3),INJOUT(4),INJOUT(5),INPTYP(1)
 2050 FORMAT(2X,'2  INCIN. PROP. PRINTED IF = 1',T45,I3/
     12X,'3  DROP OUTPUT PRINTED IF = 1',T45,I3/
     22X,'4  FINAL SUMMARY PRINTED IF = 1',T45,I3/
     32X,'5  TURNS ON GRAVITY IF = 1',T45,I3/
     52X,'6  DUMMY TWALL IS READ IF = 1',T45,I3)
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      WRITE(6,2060) INPTYP(2),INPTYP(3),INPTYP(4),INPTYP(5),INPTYP(6)
 2060 FORMAT(2X,'7  DUMMY GAS TEMP. USED IF = 1',T45,I3/
     22X,'8  DUMMY X VELOCITY USED IF = 1',T45,I3/
     32X,'9  DUMMY Y VELOCITY USED IF = 1',T45,I3/
     41X,'10  TANG. VELOCITY SET WITH SWIRL IF 1',T45,I3/
     51X,'11  TURBULENCE IS USED IF = 1',T45,I3)
C
      WRITE (6,2070) TWDUM,TGDUM UDUM,VDUM,SWIRL,TOTLEN,JLAYER,
     1               JFORCE,TIMAX
 2070 FORMAT(1X,'12  DUMMY WALL TEMPERATURE  (K)',T45,F9.4/
     21X,'13  DUMMY GAS TEMPERATURE  (K)',T45,F9.4)
     31X,'14  DUMMY X VELOCITY',T45,F9.4/
     41X,'15  DUMMY Y VELOCITY',T45,F9.4/
     51X,'16  SWIRL NUMBER',T45,F4.1/
     61X,'17  TOTAL FURNACE LENGTH  (M)',T45,F9.3/
     71X,'18  NO. OF INNER ZONES FOR BOUNDARY LAYER',T45,I2/
     81X,'19  NO. OF OUTER ZONES FOR FORCED VORTEX',T45,I2/
     91X,'20  NO. OF TURBULENT RUNS',T45,I10)
C
      WRITE (6,2080)
 2080 FORMAT(/2X,'TYPE THE ITEM NUMBER (1-20) TO BE CHANGED.'/2X,
     1'TYPE  21  IF NO CHANGES ARE TO BE MADE.  ')
      READ (5,*) CHANGE3
      GO TO (2121,2122,2123,2124,2125,2127,2128,2129,2130,2142,2143,
     12131,2132,2133,2134,2135,2136,2137,2138,2139,2140), CHANGE3
C
 2101 WRITE (6,2201)
 2201 FORMAT (2X,'TYPE THE NEW NAME OF THE SPECIES  ')
      READ (5,1000) (INCASE(I),I=1,40)
      GO TO 2000
C
 2102 WRITE (6,2202)
 2202 FORMAT (2X,'TYPE THE NEW LIQUID BOILING TEMPERATURE (K)  ')
      READ (5,*) TBOIL
      GO TO 2000
C
 2103 WRITE( 6,2203)
 2203 FORMAT(2X,'TYPE THE NEW INITITAL DROPLET TEMPERATURE (K)  ')
      READ (5,*) TLIQ
      GO TO 2000
C
 2104 WRITE (6,2204)
 2204 FORMAT (2X,'TYPE THE NEW LIQUID HEAT CAPACITY (M**2/S**2/K)  ')
      READ (5,*) CPLIQ
      GO TO 2000
C
 2105 WRITE(6,2205)
 2205 FORMAT(2X,'TYPE THE NEW LATENT HEAT OF EVAPORATION (M**2/S**2)  ')
      READ (5,*) LHELIQ
      GO TO 2000
C
 2106 WRITE (6,2206)
 2206 FORMAT(2X,'TYPE THE NEW LIQUID DENSITY (KG/M**3)   ')
      READ (5,*) RHOLIQ
      GO TO 2000
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C
 2141 WRITE (6,2241)
 2241 FORMAT(2X,'TYPE THE NEW HEAT OF COMBUSTION (      )    ')
      READ (5,*) HCOMLQ
      GO TO 2000
C
 2107 WRITE (6,2207)
 2207 FORMAT (2X,'TYPE THE NEW X, Y AND Z COORDINATES FOR THE NOZZLE  ')
      READ (5,*) XNOZ,YNOZ,ZNOZ
      GO TO 2000
C
 2108 WRITE(6,2208)
 2208 FORMAT (2X,'TYPE THE NEW NOZZLE DIAMETER (M)  '/2X,
     1'IF THE NOZZLE DIAMETER WILL NOT AFFECT DROPLET VELOCITY, '/
     22X,'USE A NEGATIVE NUMBER   ')
      READ (5,*) NOZDIA
      GO TO 2000
C
 2109 WRITE (6,2209)
 2209 FORMAT (2X,'TYPE THE NEW AIR/FUEL MASS RATIO  ')
      READ (5,*) AFMRAT
      GO TO 2000
C
 2110 WRITE (6,2210)
 2210 FORMAT (2X,'TYPE THE NEW ZONE SAFETY FACTOR    ')
      READ (5,*) ZSAFE
      GO TO 2000
C
 2111 WRITE (6,2211)
 2211 FORMAT(2X,'TYPE THE NEW DRAG TIMESTEP SAFETY FACTOR    ')
      READ (5,*)  DSAFE
      GO TO 2000
C
 2112 WRITE (6,2212)
 2212 FORMAT(2X,'TYPE THE NEW TEMP. TIMESTEP SAFETY FACTOR    ')
      READ (5,*)  TSAFE
      GO TO 2000
C
 2113 WRITE (6,2213)
 2213 FORMAT(2X,'TYPE THE NEW EVAP. TIMESTEP SAFETY FACTOR    ')
      READ (5,*)  ESAFE
      GO TO 2000
C
 2114 WRITE (6,2214)
 2214 FORMAT(2X,'TYPE NEW TOLERANCE FOR EVAP. VELOCITY      ')
      READ (5,*) TOL1
      GO TO 2000
C
 2115 WRITE (6,2215)
 2215 FORMAT (2X,'TYPE THE NEW RAMP FOR TIMESTEP    ')
      READ (5,*) NRAMP
      GO TO 2000
C
 2116 WRITE (6,2216)
 2216 FORMAT(2X,'TYPE THE NEW MAX. NO. OF STEPS  ')
```

```
      READ (5,*) MAXSTP
      GO TO 2000
C
 2117 WRITE (6,2217)
 2217 FORMAT (2X,'TYPE THE NEW NUMBER OF DROPLETS   ')
      READ (5,*) NDROP
      GO TO 2000
C
 2118 WRITE (6,2218)
 2218 FORMAT(2X,'TYPE THE NEW TIMESTEP FOR PRINTOUT TO BEGIN   ')
      READ (5,*) NPRT1
      GO TO 2000
C
 2119 WRITE (6,2219)
 2219 FORMAT (2X,'TYPE THE NEW TIMESTEP INCREMENT FOR PRINTOUT   ')
      READ (5,*) NPRT2
      GO TO 2000
C
 2120 WRITE (6,2220)
 2220 FORMAT (2X,'TYPE THE NEW INCREMENT COUNTER FOR INJECTED DROPS  ')
      READ (5,*) NPRT3
      GO TO 2000
C
 2121 WRITE (6,2221)
 2221 FORMAT(2X,'TYPE THE NEW FLAG FOR GAS PROPERTIES   ')
      READ (5,*) INJOUT(1)
      GO TO 2049
C
 2122 WRITE (6,2222)
 2222 FORMAT(2X,'TYPE THE NEW FLAG FOR INCIN. PROPERTIES   ')
      READ (5,*) INJOUT(2)
      GO TO 2049
C
 2123 WRITE (6,2223)
 2223 FORMAT(2X,'TYPE THE NEW FLAG FOR PRINTING OUTPUT   ')
      READ (5,*) INJOUT(3)
      GO TO 2049
C
 2124 WRITE (6,2224)
 2224 FORMAT(2X,'TYPE THE NEW FLAG FOR PRINTING RESULTS  ')
      READ (5,*) INJOUT(4)
      GO TO 2049
C
 2125 WRITE (6,2225)
 2225 FORMAT(2X,'TYPE THE NEW FLAG FOR USING GRAVITY  ')
      READ (5,*) INJOUT(5)
      GO TO 2049
C
 2127 WRITE (6,2227)
 2227 FORMAT(2X,'TYPE THE NEW DUMMY TWALL FLAG   ')
      READ (5,*) INPTYP(1)
      GO TO 2049
C
 2128 WRITE (6,2228)
 2228 FORMAT(2X,'TYPE THE NEW DUMMY GAS TEMPERATURE FLAG   ')
```

```
      READ (5,*) INPTYP(2)
      GO TO 2049
C
 2129 WRITE (6,2229)
 2229 FORMAT(2X,'TYPE THE NEW DUMMY X VELOCITY FLAG    ')
      READ (5,*) INPTYP(3)
      GO TO 2049
C
 2130 WRITE (6,2230)
 2230 FORMAT(2X,'TYPE THE NEW DUMMY Y VELOCITY FLAG    ')
      READ (5,*) INPTYP(4)
      GO TO 2049
C
 2142 WRITE (6,2242)
 2242 FORMAT(2X,'TYPE THE NEW DUMMY Y VELOCITY FLAG    ')
      READ (5,*) INPTYP(5)
      GO TO 2049
C
 2143 WRITE (6,2243)
 2243 FORMAT(2X,'TYPE THE NEW DUMMY Y VELOCITY FLAG    ')
      READ (5,*) INPTYP(6)
      GO TO 2049
C
 2131 WRITE (6,2231)
 2231 FORMAT(2X,'TYPE THE NEW DUMMY WALL TEMPERATURE (K)   ')
      READ (5,*) TWDUM
      GO TO 2049
C
 2132 WRITE (6,2232)
 2232 FORMAT(2X,'TYPE THE NEW DUMMY GAS TEMPERATURE (K)   ')
      READ (5,*) TGDUM
      GO TO 2049
C
 2133 WRITE (6,2233)
 2233 FORMAT(2X,'TYPE THE NEW DUMMY X VELOCITY  (M/S)    ')
      READ (5,*) UDUM
      GO TO 2049
C
 2134 WRITE (6,2234)
 2234 FORMAT(2X,'TYPE THE NEW DUMMY Y VELOCITY  (M/S)   ')
      READ (5,*) VDUM
      GO TO 2049
C
 2135 WRITE (6,2235)
 2235 FORMAT(2X,'TYPE THE NEW SWIRL NUMBER       ')
      READ (5,*) SWIRL
      GO TO 2049
C
 2136 WRITE (6,2236)
 2236 FORMAT(2X,'TYPE THE NEW TOTAL FURNACE LENGTH  (M)   ')
      READ (5,*) TOTLEN
      GO TO 2049
C
 2137 WRITE (6,2237)
 2237 FORMAT (2X,'TYPE THE NUMBER OF ZONES FOR BOUNDARY LAYER   ')
```

```
      READ (5,*) JLAYER
      GO TO 2049
C
 2138 WRITE (6,2238)
 2238 FORMAT (2X,'TYPE THE NUMBER OF ZONES FOR FORCED VORTEX    ')
      READ (5,*) JFORCE
      GO TO 2049
C
 2139 WRITE (6,2239)
 2239 FORMAT (2X,'TYPE THE NO. OF TURBULENT RUNS    ')
      READ (5,*) TIMAX
      GO TO 2049
C
 2140 WRITE (7,1000) (INCASE(I), I=1,40)
      WRITE (7,2300) TBOIL,TLIQ
 2300 FORMAT ('TBOIL  :',F10.4,' TLIQ   :',F10.4)
      WRITE (7,2310) CPLIQ,LHELIQ
 2310 FORMAT ('CPLIQ  :',F10.4,' LHELIQ :',E10.4)
      WRITE (7,2315) HCOMLQ
 2310 FORMAT ('HCOMLQ :',E10.3)
      WRITE (7,2320) RHOLIQ,XNOZ
 2320 FORMAT ('RHOLIQ :',F10.4,' XNOZ   :',F10.4)
      WRITE (7,2330) YNOZ, ZNOZ
 2330 FORMAT ('YNOZ   :',F10.4,' ZNOZ   :',F10.4)
      WRITE (7,2340) NOZDIA,AFMRAT
 2340 FORMAT ('NOZDIA :',E10.4,' AFMRAT :',F10.4)
      WRITE (7,2350) ZSAFE,DSAFE
 2350 FORMAT ('ZSAFE  :',F10.4,' DSAFE  :',F10.4)
      WRITE (7,2360) TSAFE,ESAFE
 2360 FORMAT ('TSAFE  :',F10.4,' ESAFE  :',F10.4)
      WRITE (7,2370) TOL1,NRAMP
 2370 FORMAT('TOL1   :',F10.4,' NRAMP  :',I10)
      WRITE (7,2380) MAXSTP,NDROP
 2380 FORMAT('MAXSTP :',I10/'NDROP  :',I10)
      WRITE (7,2390) NPRT1,NPRT2
 2390 FORMAT('NPRT1  :',I10/'NPRT2  :',I10)
      WRITE (7,2400) NPRT3
 2400 FORMAT('NPRT3  :',I10)
      WRITE (7,2410) INJOUT(1),INJOUT(2)
 2410 FORMAT('INJOUT1:',I10/'INJOUT2:',I10)
      WRITE (7,2420) INJOUT(3),INJOUT(4)
 2420 FORMAT('INJOUT3:',I10/'INJOUT4:',I10)
      WRITE (7,2430) INJOUT(5),INJOUT(6)
 2430 FORMAT('INJOUT5:',I10/'INJOUT6:',I10)
      WRITE (7,2440) INPTYP(1),INPTYP(2)
 2440 FORMAT('INPTYP1:',I10/'INPTYP2:',I10)
      WRITE (7,2450) INPTYP(3),INPTYP(4)
 2450 FORMAT('INPTYP3:',I10/'INPTYP4:',I10)
      WRITE (7,2460) INPTYP(5),INPTYP(6)
 2460 FORMAT('INPTYP5:',I10/'INPTYP6:',I10)
      WRITE (7,2470) TWDUM,TGDUM
 2470 FORMAT ('TWDUM  :',F10.4,' TGDUM  :',F10.4)
      WRITE (7,2480) UDUM,VDUM
 2480 FORMAT('UDUM   :',F10.4,' VDUM   :',F10.4)
      WRITE (7,2490) SWIRL,TOTLEN
 2490 FORMAT ('SWIRL  :',F10.4,' TOTLEN :',F10.4)
      WRITE (7,2495) JLAYER,JFORCE
 2495 FORMAT ('JLAYER :',I10/'JFORCE :',I10)
      WRITE (7,2496) TIMAX
 2496 FORMAT ('SPACE  :',I10)
C
C
C
 2500 WRITE(6,2510)
 2510 FORMAT(//////////2X,'THE FOLLOWING DATA DESCRIBES THE DROPLET ',
     1'WHICH IS',/2X,'INJECTED INTO THE FURNACE'//)
      WRITE(6,2520) DINIT,DRPVEL,XPCOMP,YPCOMP,ZPCOMP,LOD
 2520 FORMAT(2X,'1  INITIAL DROPLET DIAMETER  (M)',T50,E8.2/
     12X,'2  INITIAL VELOCITY OF DROPLET  (M/S)',T48,F6.2/
     22X,'3  X COMPONENT OF VELOCITY ',T50,F6.4/
     32X,'4  Y COMPONENT OF VELOCITY ',T50,F6.4/
     42X,'5  Z COMPONENT OF VELOCITY ',T50,F6.4/
     52X,'6  INITIAL DROPLET SPACING (L/D)',T50,F8.2)
C
      WRITE (6,2570)
 2570 FORMAT (/2X,'TYPE THE NUMBER OF THE DATA TO BE CHANGED (1-6) OR ',
     1'TYPE 7'/2X,'TO SAVE THE CURRENT DATA   ')
      READ (5,*) CHANGE3
      GO TO (2580,2600,2620,2640,2660,2680,2700), CHANGE3
C
 2580 WRITE(6,2590)
 2590 FORMAT(5X,'TYPE THE NEW DROPLET DIAMETER  ')
      READ (5,*) DINIT
      GO TO 2500
C
 2600 WRITE (6,2610)
 2610 FORMAT (5X,'TYPE THE NEW INITIAL VELOCITY OF DROPLET   ')
      READ (5,*) DRPVEL
      GO TO 2500
C
 2620 WRITE (6,2630)
 2630 FORMAT (5X,'TYPE THE NEW INITIAL X COMPONENT OF VELOCITY   ')
      READ (5,*) XPCOMP
      GO TO 2500
C
 2640 WRITE (6,2650)
 2650 FORMAT (5X,'TYPE THE NEW INITIAL Y COMPONENT OF VELOCITY   ')
      READ (5,*) YPCOMP
      GO TO 2500
C
 2660 WRITE (6,2670)
 2670 FORMAT (5X,'TYPE THE NEW INITIAL Z COMPONENT OF VELOCITY   ')
      READ (5,*) ZPCOMP
      GO TO 2500
C
 2680 WRITE (6,2690)
 2690 FORMAT (5X,'TYPE THE NEW INITIAL DROPLET SPACING   ')
      READ (5,*) LOD
      GO TO 2500
C
```

```
 2700 WRITE (7,2710) DINIT
 2710 FORMAT ('DINIT  :',E10.3)
      WRITE (7,2720) DRPVEL
 2720 FORMAT ('DRPVEL :',F10.4)
      WRITE (7,2730) XPCOMP
 2730 FORMAT ('XPCOMP :',F10.4)
      WRITE (7,2740) YPCOMP
 2740 FORMAT ('YPCOMP :',F10.4)
      WRITE (7,2750) ZPCOMP
 2750 FORMAT ('ZPCOMP :',F10.4)
      WRITE (7,2760) LOD
 2760 FORMAT ('L/D    :',F10.4)
C
      CLOSE (UNIT=7)
      STOP
      END
```

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modeling of the physical process, if care is not taken in selecting an appropriate grid size.

The third method for applying turbulence is based on the Prandtl mixing length as defined by classical turbulence theory. In this case the length scale for the turbulent fluctuation is translated to a time scale, during which a single fluctuation is applied. At the end of the given time period, a new fluctuation is determined and applied to the mean velocity of the current zone.

The approach which was employed in the final version of the code is the one which is described as the second method. Different turbulent fluctuations are applied to the velocity of each grid location, and in fact different fluctuations are applied to the three different velocity vectors--x, y, and z--in the same grid location. This provides for a greater degree of independence in the background gas velocities, so that a droplet traveling through the gas will not see a field in which the velocities are all skewed high or skewed low. As mentioned previously, it is assumed in this case that the turbulent fluctuations exist over a distance of one grid length. The user must take care when defining the grid that this is a reasonable assumption, and the grid size is on the same order of magnitude as the Prandtl mixing length.

4.4 Temperature Profiles

The temperature within the incinerator is also specified by means of an input file. The temperatures can be specified for each zone, or an overall default temperature can be set, forcing the entire field to be uniform. Since the density, thermal conductivity, specific heat and viscosity depend on the temperature and composition of the gas alone, constant temperature and uniform gas composition make these properties constant across the flow field.

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